

Application of XP-SWMM to the KISSIMMEE BASIN

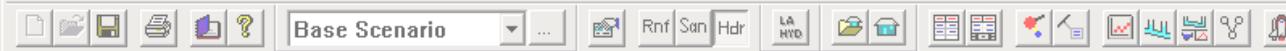


Recent Relative XP Software Experience

- XP Software ported the UKISS model to Windows
- We also added graphics and refined some of the algorithms
- Recently integrated a 2-D model with XP-SWMM for overland flows
- New framework permits further development to distributed catchment modeling

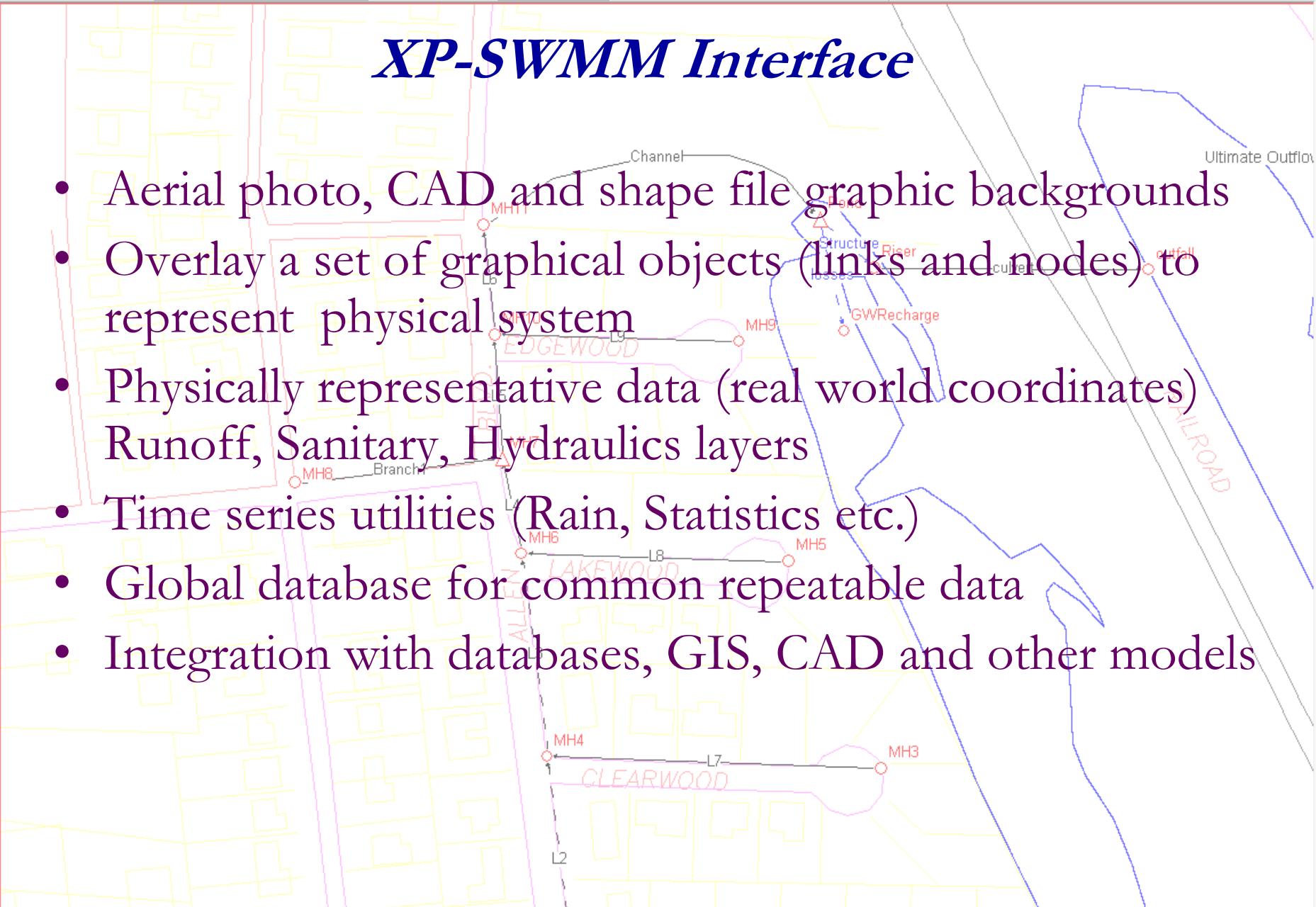
Description of XP-SWMM

- Modeling software for watershed, river, storm and wastewater management
- Decision support system encompassing a graphical user interface and an analytical engine
- The XP interface stands for the embedded eXPert system
- Analytical engine is based on EPA SWMM and contains numerous proprietary enhancements



Base Scenario

- # *XP-SWMM Interface*
- Aerial photo, CAD and shape file graphic backgrounds
 - Overlay a set of graphical objects (links and nodes) to represent physical system
 - Physically representative data (real world coordinates)
Runoff, Sanitary, Hydraulics layers
 - Time series utilities (Rain, Statistics etc.)
 - Global database for common repeatable data
 - Integration with databases, GIS, CAD and other models



Basin Hydrology

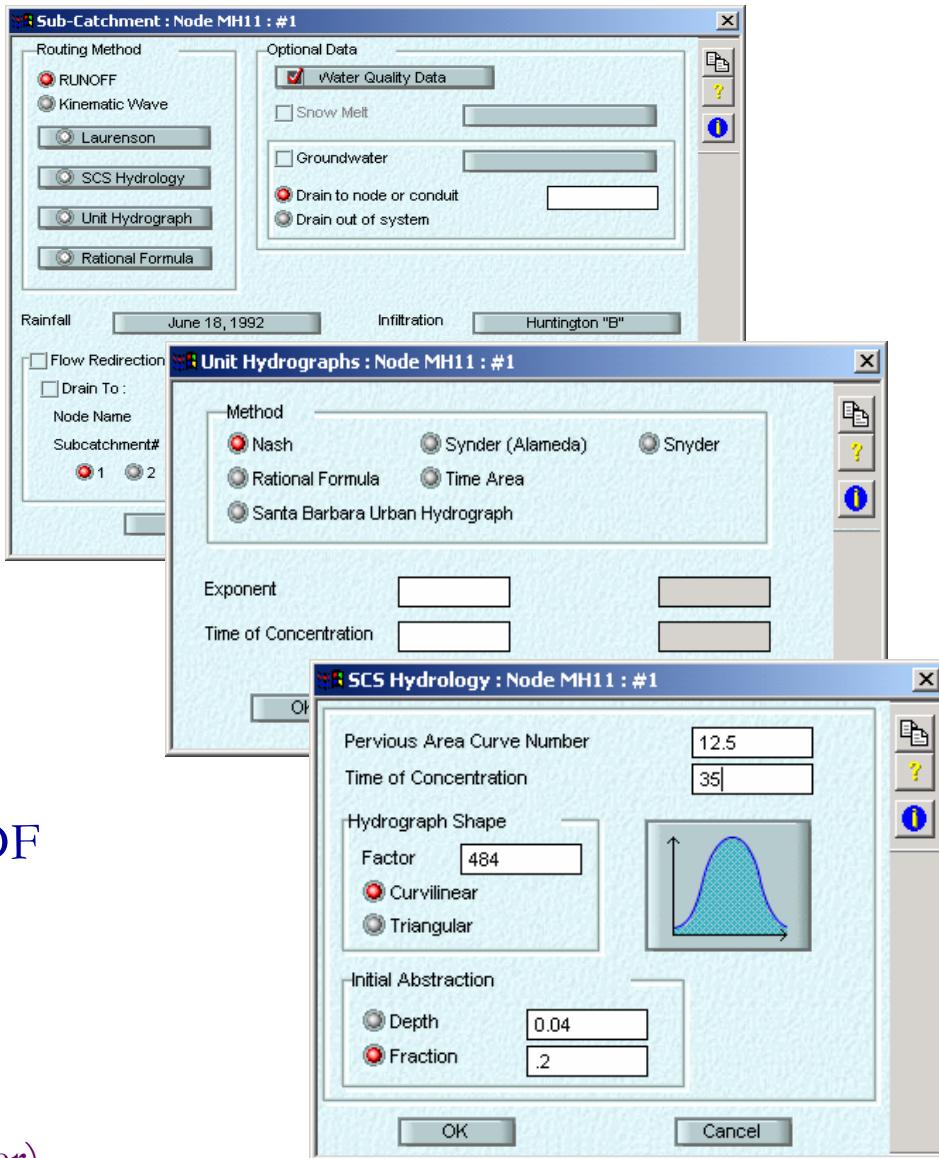
- Surface hydrograph generation using 12 methods: RUNOFF, SCS, SBUH, Kinematic wave and many other unit hydrograph methods
- RUNOFF method is a deterministic model which can simulate: rainfall, snowmelt, infiltration, evaporation, and groundwater interaction
- Continuous and event simulations
- Simulate spatial and temporal variation in rainfall
- Catchment parameters: lumped (subcatchment basis)
- Redirect surface flows – Low Impact Development
- Water quality (generate non point source pollutographs)
- Global Storms –(simulate multiple return periods)
- BMP in hydrology layer

Basin Hydrology – Losses

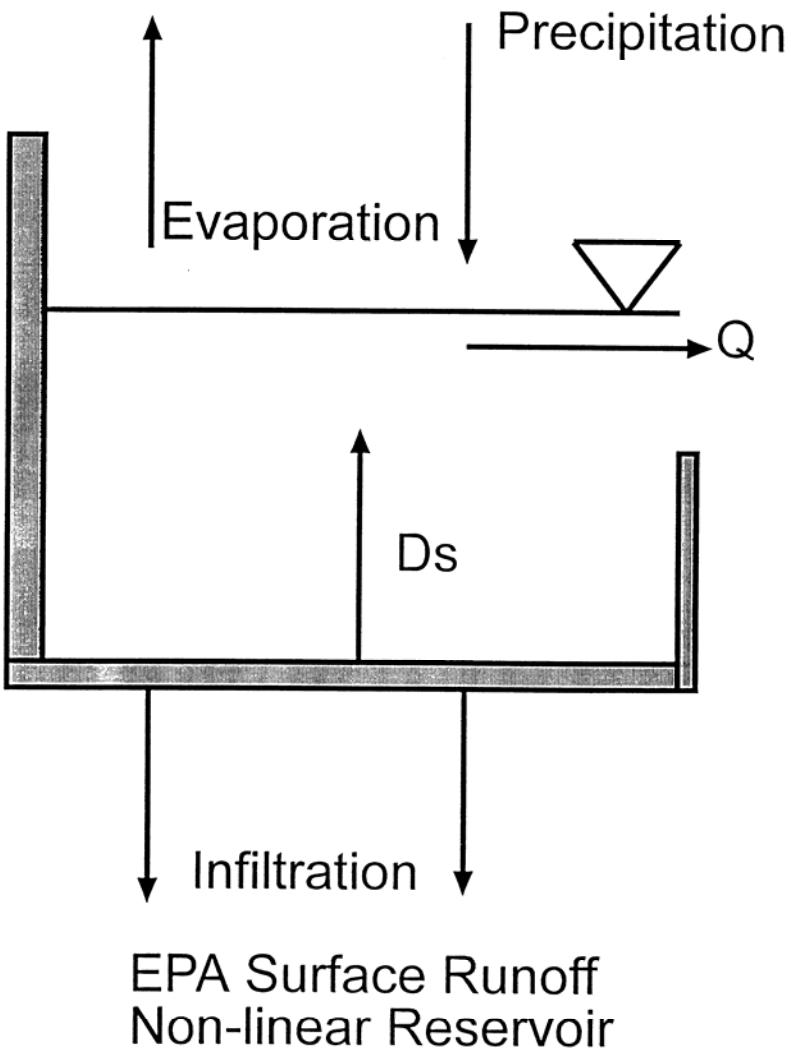
- Initial abstractions are simulated by unique depression storage depths for impervious and pervious surfaces on each subcatchment
- Infiltration by Horton, Green-Ampt and initial, proportional and continuing loss methods
- Continuous simulations infiltration capacity and surface storage is recovered
- Horton infiltration allows cumulative infiltration volume cutoff to limited soil storage
- Infiltration is optionally coupled to the groundwater
- Evaporation as daily or monthly averages
- Evaporation as a continuous time series

Hydrology Methods

- 12 different methods
 - SWMM RUNOFF
 - Kinematic Wave
 - Laurenson
 - SCS
 - Unit Hydrographs
 - SBUH
 - Snyder
 - Rational Formula
 - Time Area
 - Nash
 - Rational Method Uses IDF
 - Plus Regional Methods
 - LA County Method (MORA)
 - CUHP
 - Alameda County (Snyder)

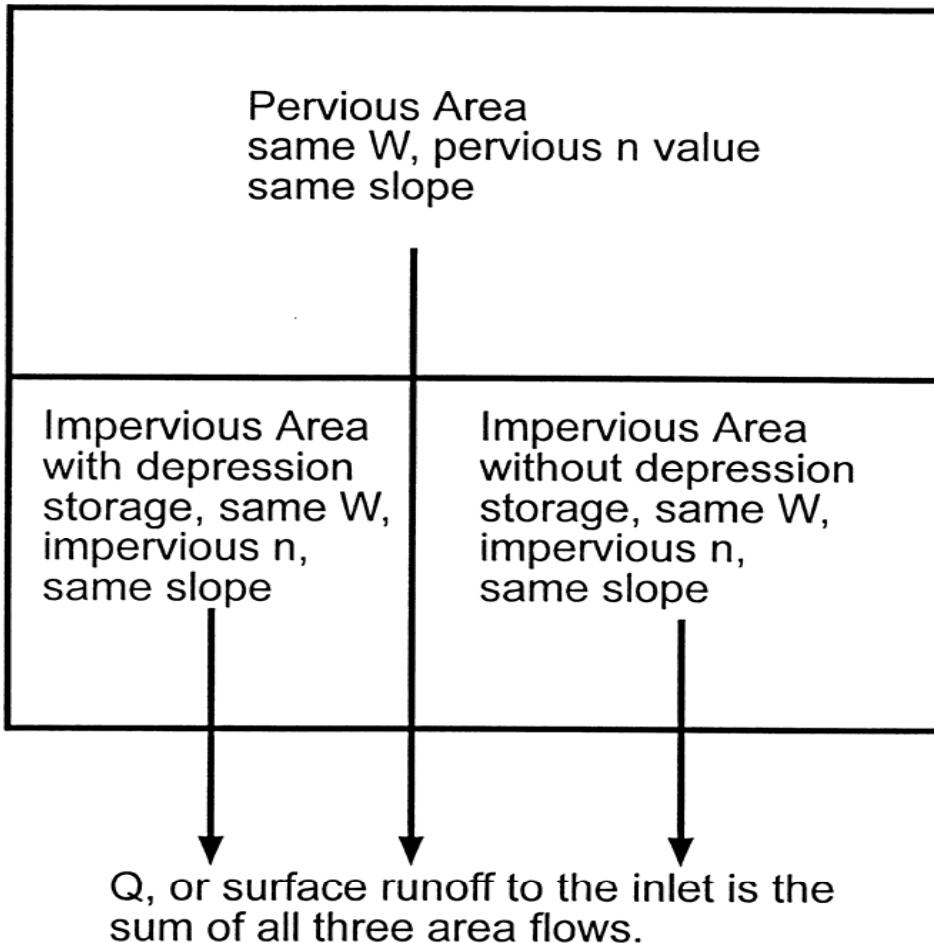


RUNOFF Layer Conceptualization



$$Q = \frac{1.486}{n} \bullet W \bullet (d - d_s)^{5/3} \bullet S^{1/2}$$

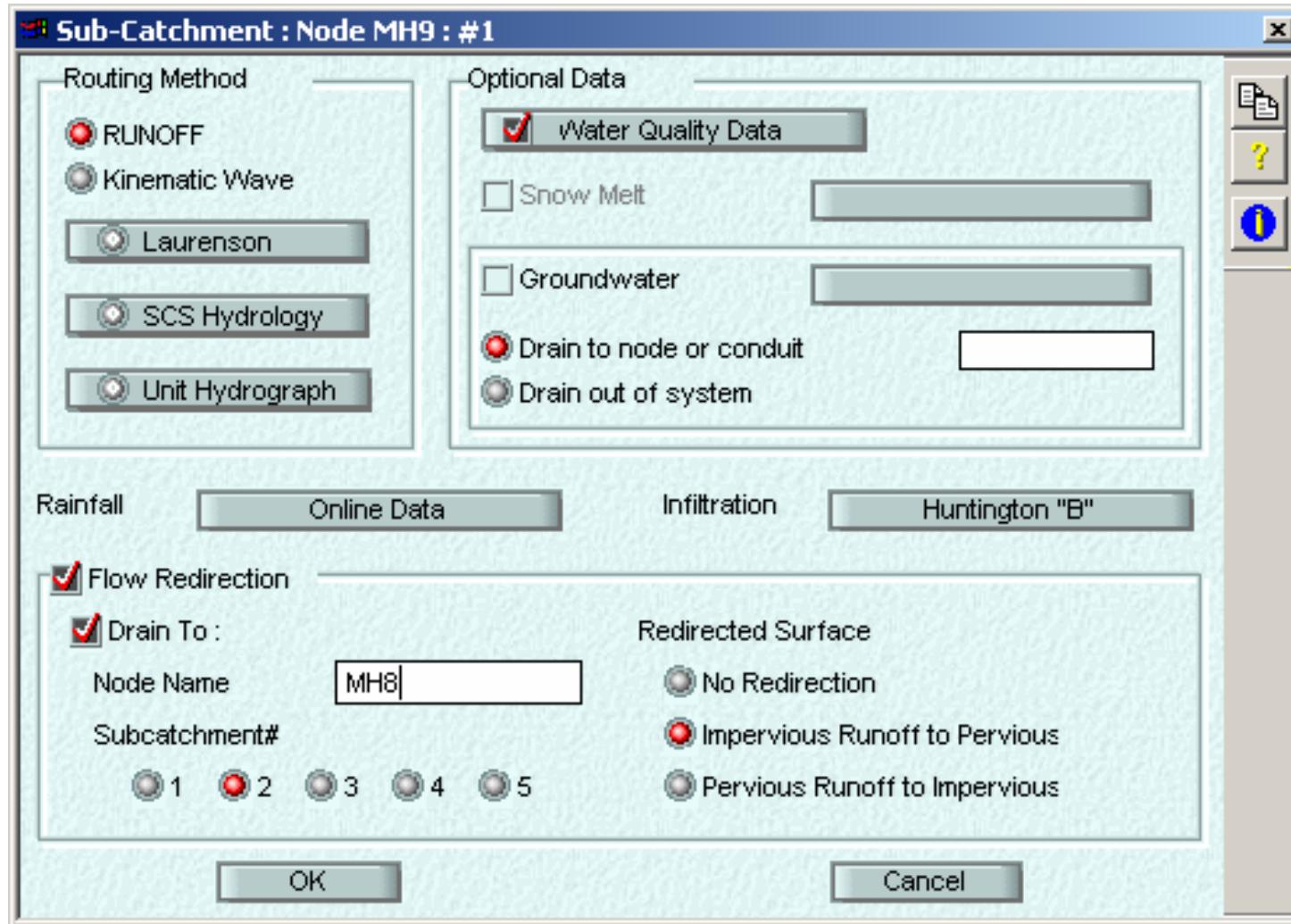
Catchment Surfaces



Note: Impervious and pervious areas have a different W/n ratio for calibration.

Surface Flow Redirection

- Redirect flows by surface and between subcatchments
- Permits LID and source control BMP modeling

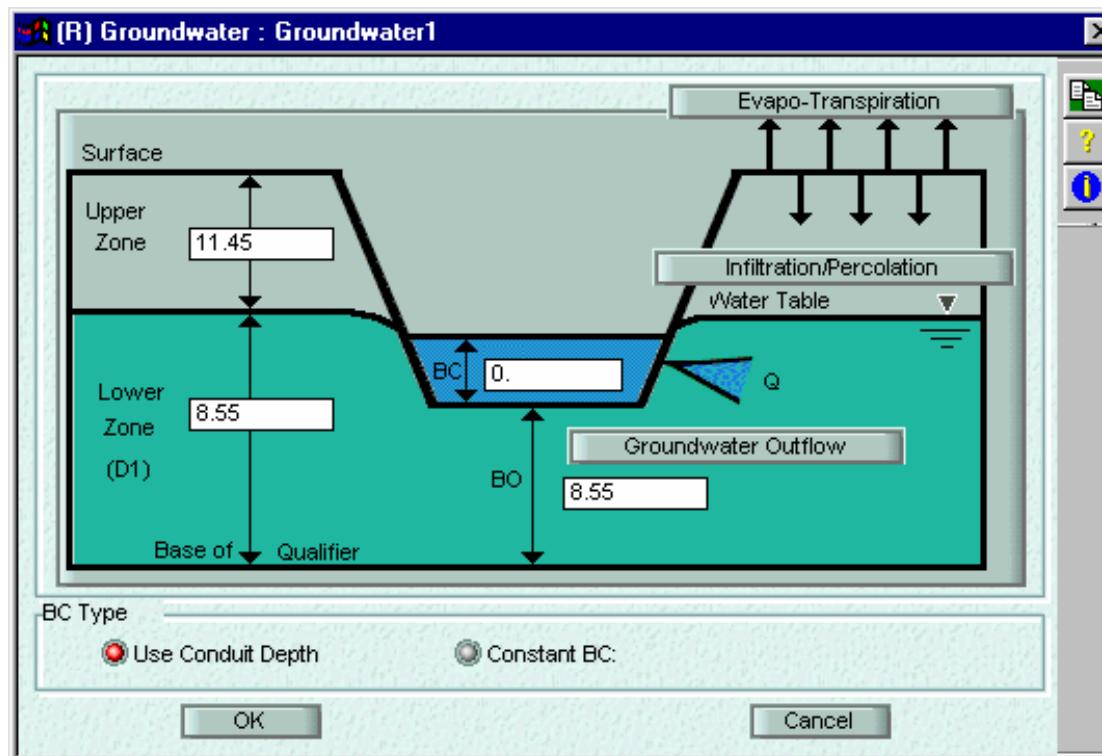


Infiltration Procedures

- Horton
- Horton with cumulative maximum infiltration
- Green-Ampt
- Initial and continuing loss
- Initial and proportional loss
- All the above optionally connected to groundwater
- Losses associated with the unit hydrograph method:
 - SCS - loss rates & fraction initial abstraction
 - SCS - loss rates & fixed depth initial abstraction

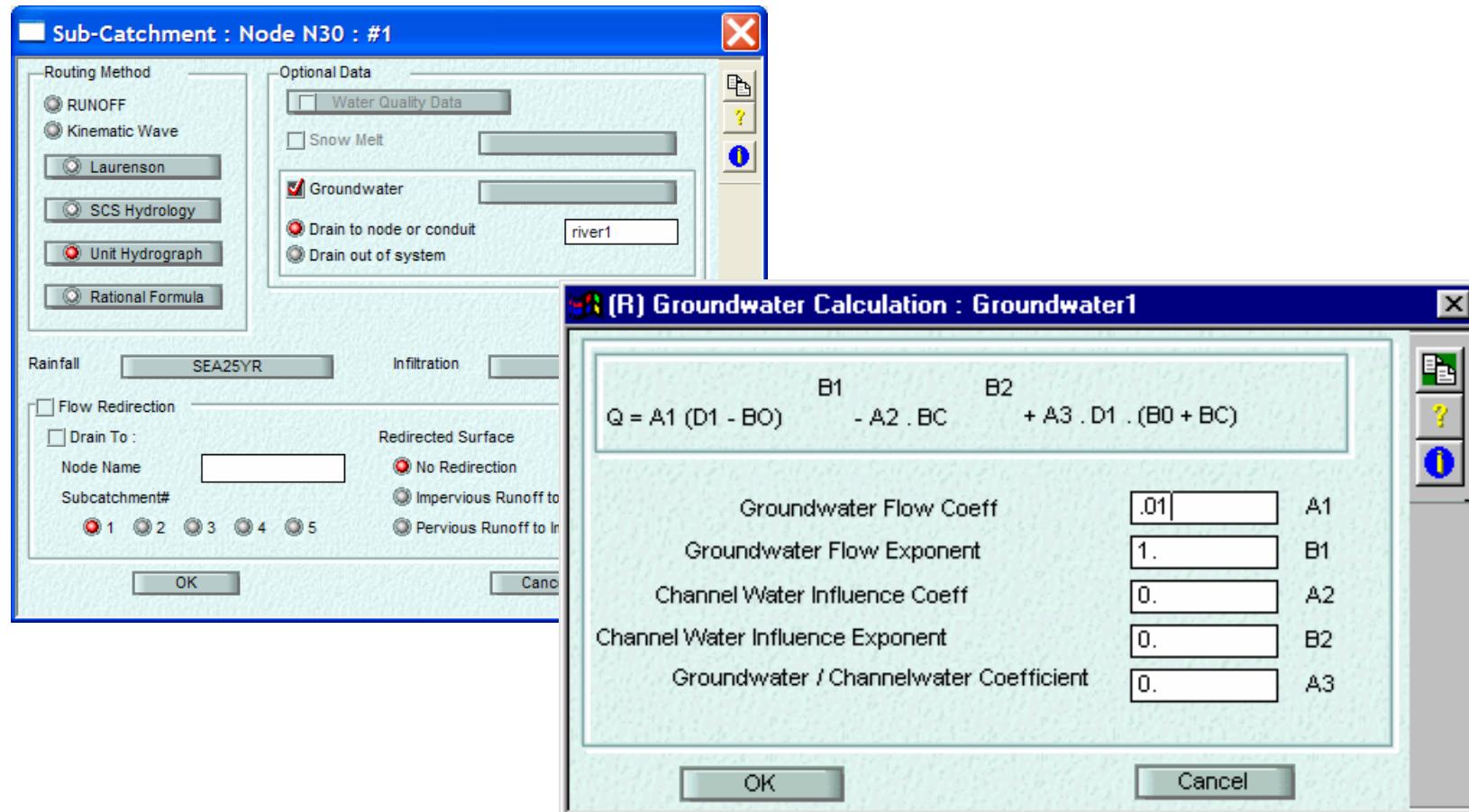
Basin Hydrology - Groundwater

- Subsurface hydrology using 2 compartment groundwater module
- Each subcatchment has its own groundwater storage
- High groundwater table can cut off infiltration
- Groundwater between subcatchments not currently simulated



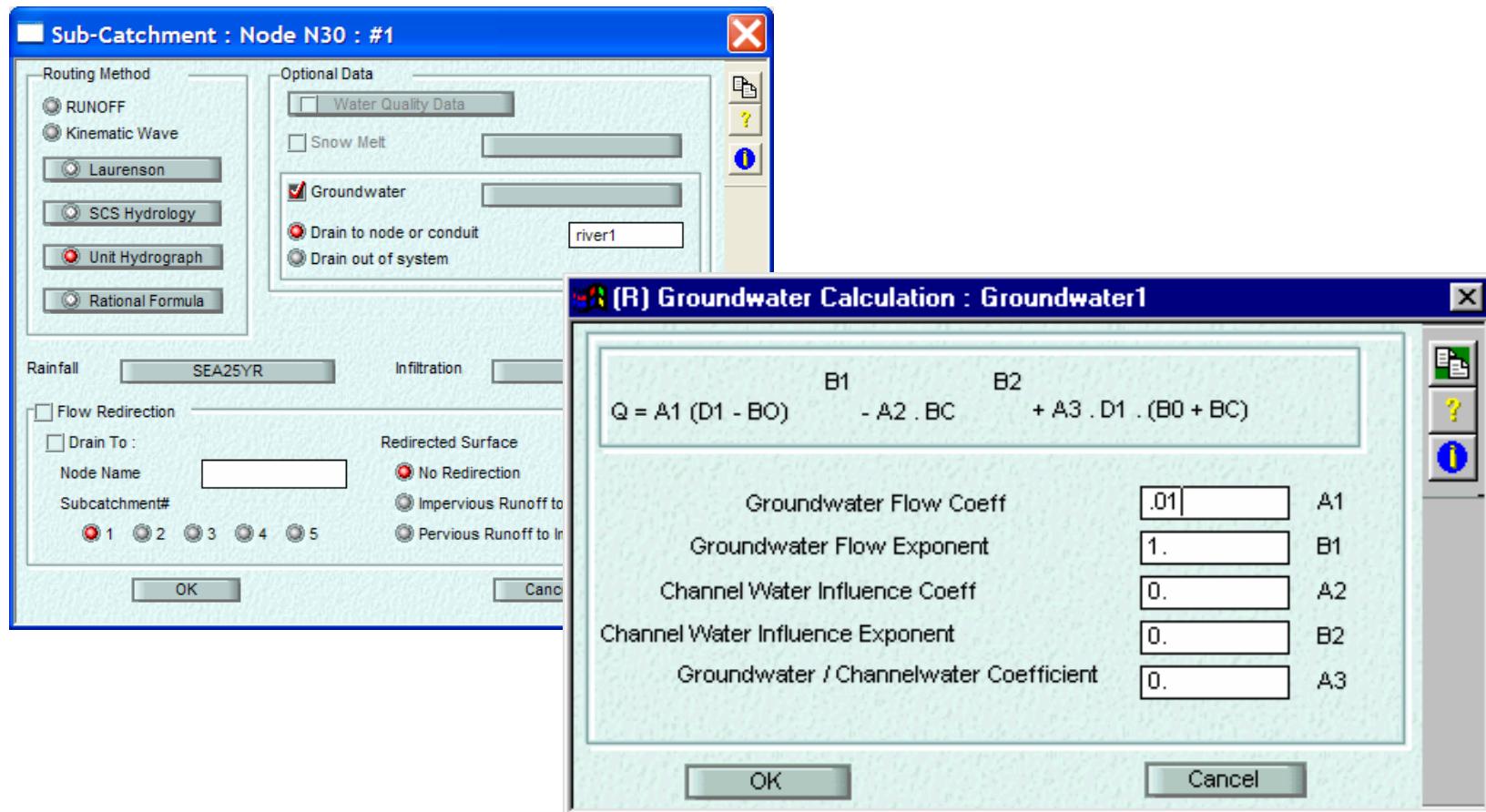
Groundwater Flows

- Groundwater flow can be redirected to other nodes or links
- Groundwater flow can be drained out of the system
- Boundary condition can be static or dynamic conduit depth



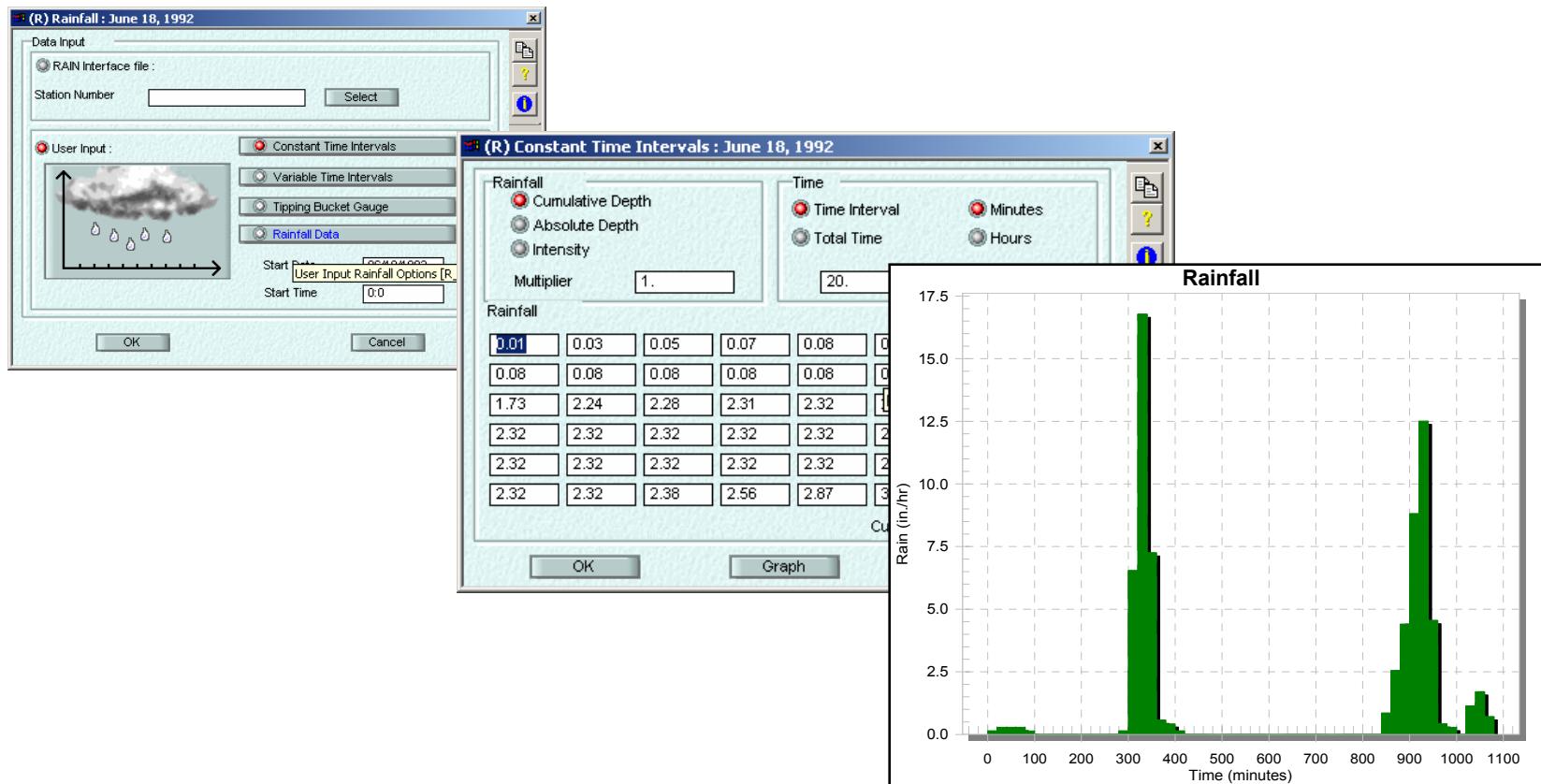
Groundwater Hydraulics

- No current groundwater interaction between subcatchments
- With software developments:
 - This could be easily simulated with a rating curve
 - XP-SWMM could be integrated with MODFLOW

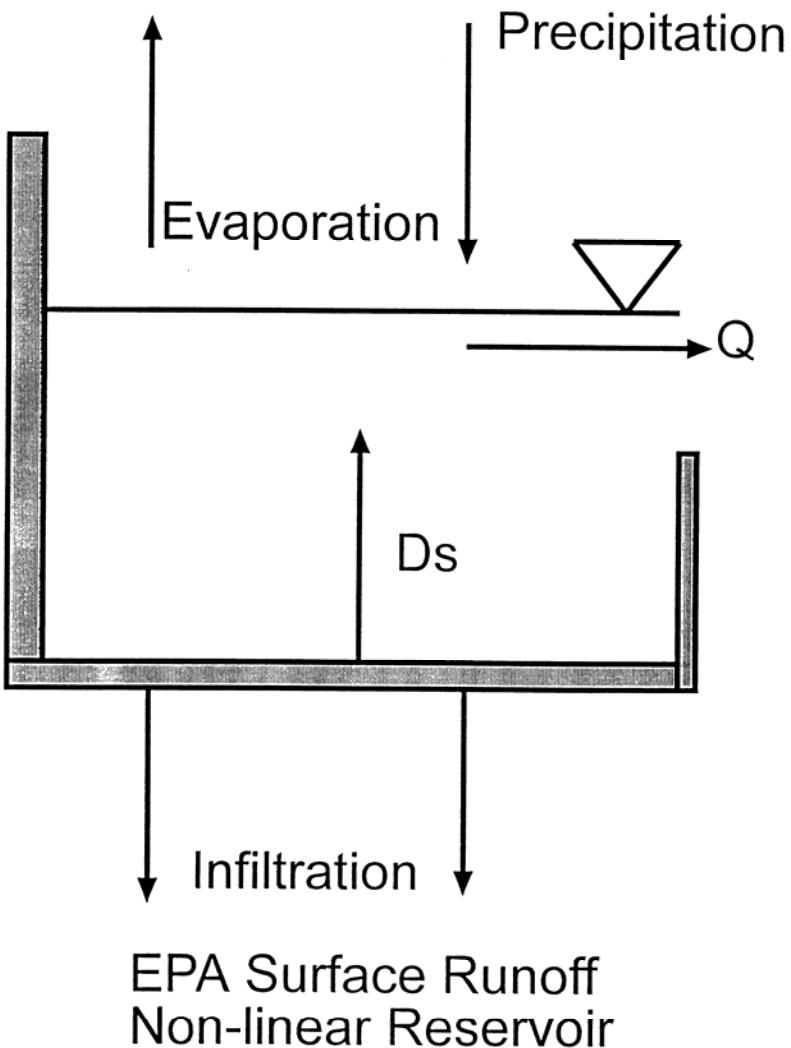


Flexible Rainfall Data Input

- Single event or continuous rainfall stored in or linked to XP
- Constant or variable time steps
- Design storms i.e. 72-hr SWFWMD
- Generate statistics on rain and graph the storms
- Import and analyze NWS, Earth Info, and user defined rainfall

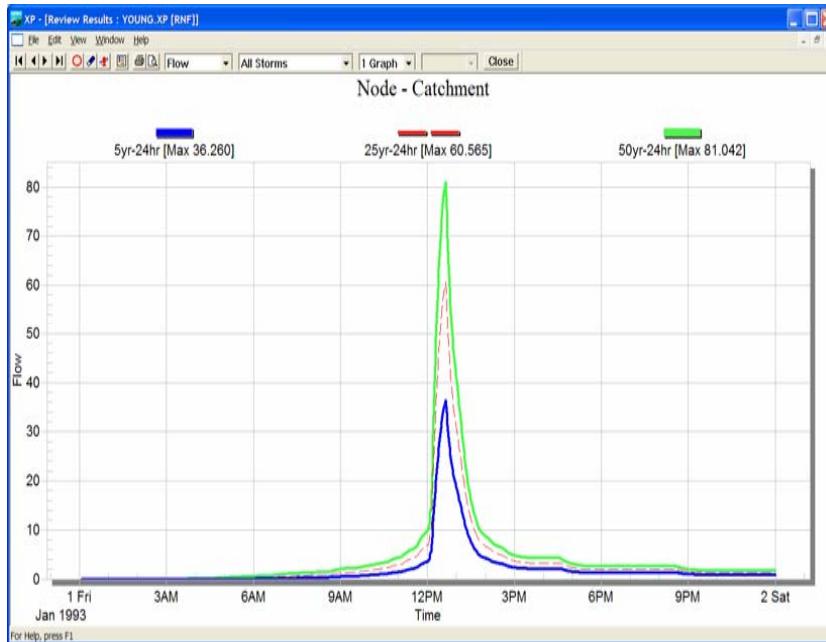


Catchment Conceptualization



$$Q = \frac{1.486}{n} \bullet W \bullet (d - d_s)^{5/3} \bullet S^{1/2}$$

Global Storms



XP - [SWMM Ver. 9.50] : YOUNG.XP:2 (Table)

File Edit View Options Format Window Help

| Graph | Close |

Name	Storm	Max Water Elevation (ft, m)	Max Surface Area (ft ² , m ²)	Node Inflow (ft ³ , m ³)
Catchment	5yr-24hr	15.000	12.57	180929.368
	25yr-24hr	15.000	12.57	309130.857
	50yr-24hr	15.000	12.57	420159.910
Pond A1	5yr-24hr	9.976	86589.44	0.000
	25yr-24hr	10.132	90949.91	0.000
	50yr-24hr	10.215	93374.81	0.000
mh a1	5yr-24hr	5.066	12.57	0.000
	25yr-24hr	5.167	12.57	0.000
	50yr-24hr	5.234	12.57	0.000
Tide Outf.	5yr-24hr	3.044	12.57	0.000
	25yr-24hr	3.160	12.57	0.000
	50yr-24hr	3.232	12.57	0.000

Pond Stage /

OVR

Global Storms

	Name	Return Period	Rainfall	Override Multiplier	Multiplier
<input checked="" type="checkbox"/>	5yr-24hr	5	SCS Type II	<input checked="" type="checkbox"/>	5.2
<input checked="" type="checkbox"/>	25yr-24hr	25	SCS Type II	<input checked="" type="checkbox"/>	7.8
<input checked="" type="checkbox"/>	50yr-24hr	100	SCS Type II	<input type="checkbox"/>	10.00

OK

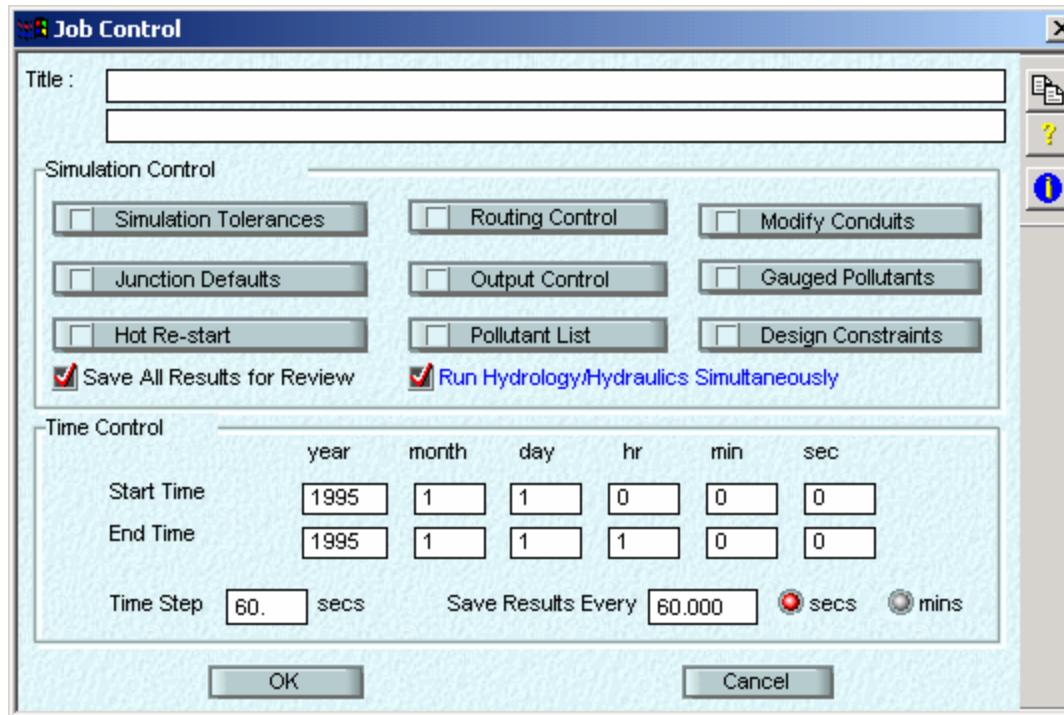
Cancel

Insert Storm

Delete Storm

Combined Hydrology and Hydraulics

- “Simultaneous” option allows Hydraulics to run at the same time as Runoff without the need for interface files.



- Dynamic depths of the conduits in Hydraulics can be linked to the Runoff groundwater module.

Hydraulics (Extran) Layer

- Dynamic wave routing (St. Venant equations)
- Fast solution with variable time step
- Handles multiple boundary conditions
- Simulates networks of open and closed conduits
- Handles multiple conduits, pumps, weirs, orifices
- Handles looped networks & adverse sloped conduits
- Can also route water quality
- Has several Real Time Control elements & capabilities
- Superior solution (more stable & capable than EPA)
- Inlet capacity analysis for dual drainage
- Real Time Control module (add-on)

St. Venant Equations

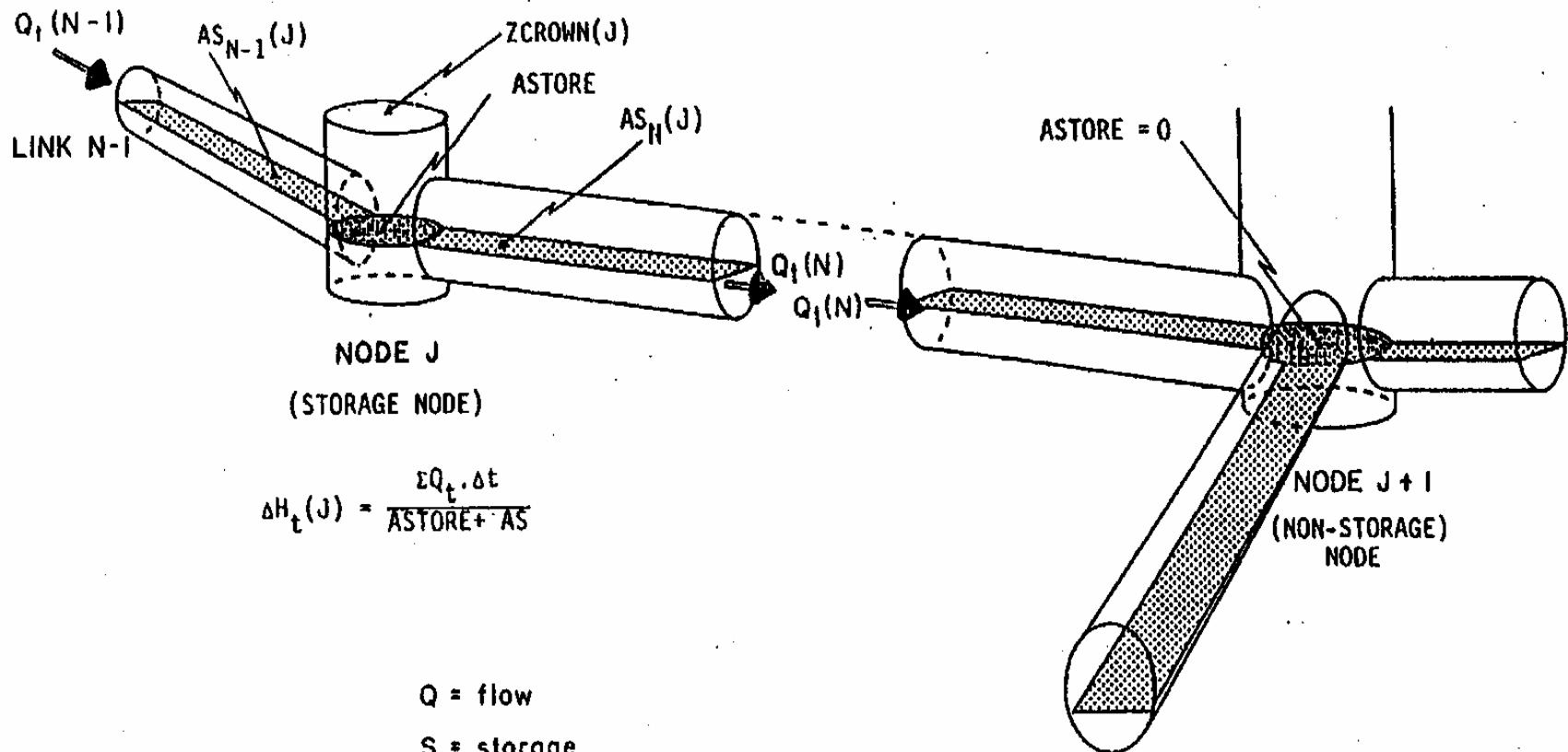
Continuity Equation: (Conserves Mass)

$$\frac{\partial \mathbf{A}}{\partial t} + \frac{\partial \mathbf{Q}}{\partial \mathbf{x}} = \mathbf{0}$$

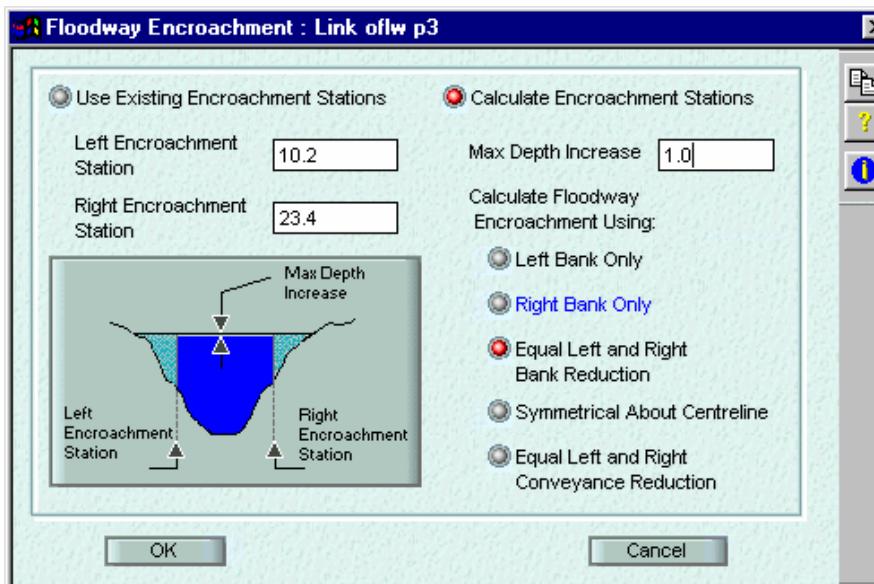
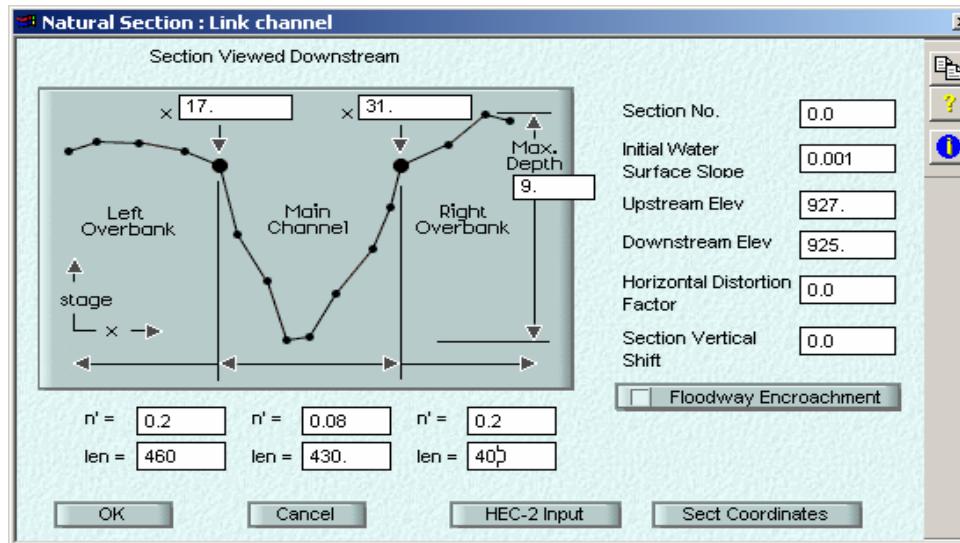
Momentum Equation:(Conserves Energy)

$$\frac{\partial \mathbf{Q}}{\partial t} + \frac{\partial \left(\frac{\mathbf{Q}^2}{\mathbf{A}} \right)}{\partial \mathbf{x}} + g\mathbf{A} \frac{\partial \mathbf{y}}{\partial \mathbf{x}} + g\mathbf{A}(S_e + S_c + S_f - S_o) = \mathbf{0}$$

Link Node Representation



Natural Channel Definition

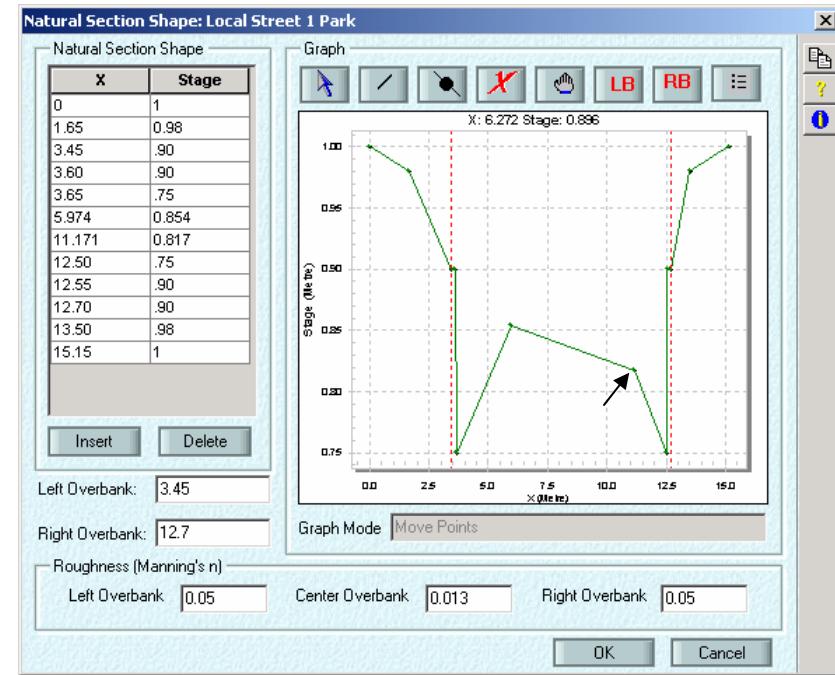
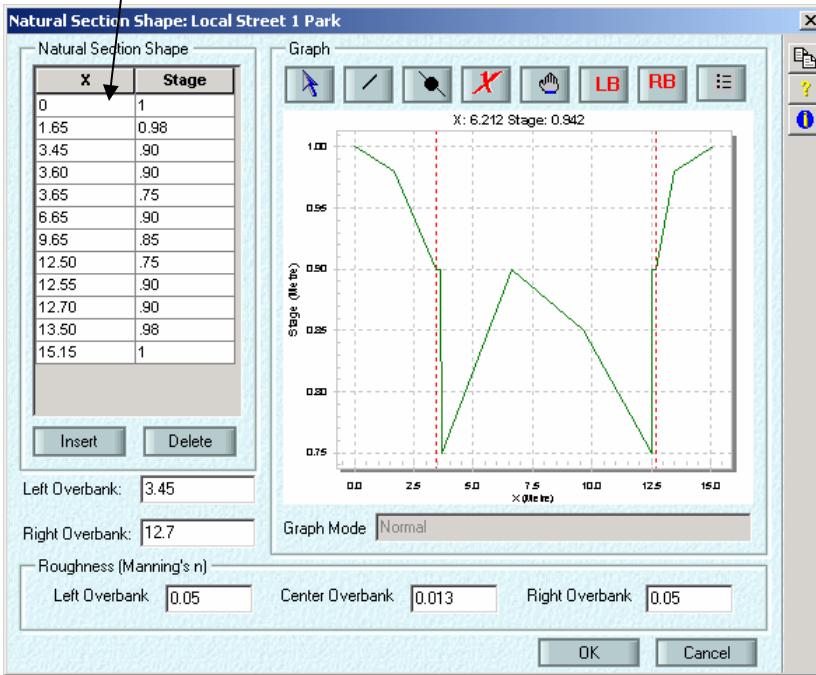


Natural Channel: Editing

A screenshot of Microsoft Excel showing a table titled "Street Profiles". The table has columns "Station" and "Elevation". The data includes rows for Sidewalk, Boulevard, Curb Top, Curb bottom, Lane, Crown, and Parking Lane. The total elevation sum is 105.86.

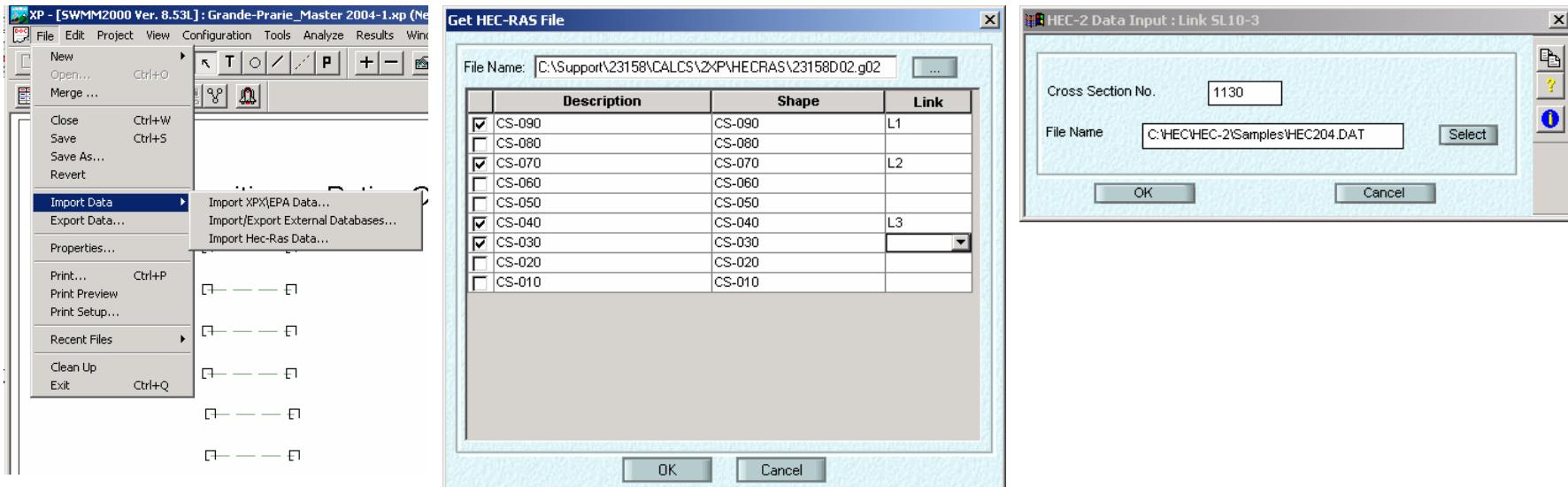
Street Profiles	
Local Street Single Parking 1 side	
Station	Elevation
0	1 Sidewalk
1.65	0.98 Boulevard
3.45	0.9 Curb Top
3.6	0.9 Curb bottom
3.65	0.75 Lane
6.65	0.9 Crown
9.65	0.85 Lane
12.5	0.75 Parking Lane
12.55	0.9 Curb bottom
12.7	0.9 Curb Top
13.5	0.98 Boulevard
15.15	1 Sidewalk

- Copy and paste cross-section geometry
- Tabular or graphic editing of channel geometry as shown below by clicking and dragging the points
- Graphically select left and right overbank stations
- Store sections in the Global Database

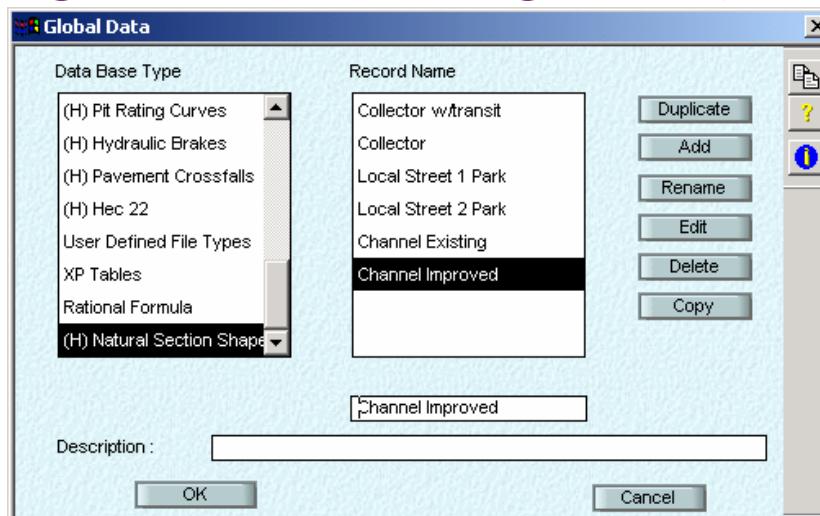


Natural Channel Import and Storage

- Import natural channel geometry from HECRAS or HEC-2



- Store and merge natural channel geometry in the global database



Hydraulic Elements and Structures

- Open and closed conduits including surcharged closed conduits
- Junctions, manholes, inlets, catchbasins and outfalls
- Inline and offline storage nodes i.e. lakes, ponds, wetlands and wide channels
- Side and bottom outlet circular and rectangular orifices
- Transverse and side flow weirs
- User defined weirs
- Pumps Rated by: dynamic head, depth or wet well volume
- Rating curves and flows specified by defined user equations
- Regulators, inflatable and bendable weirs
- Flexible BMP as storage and screening devices
- RTC of the above structures

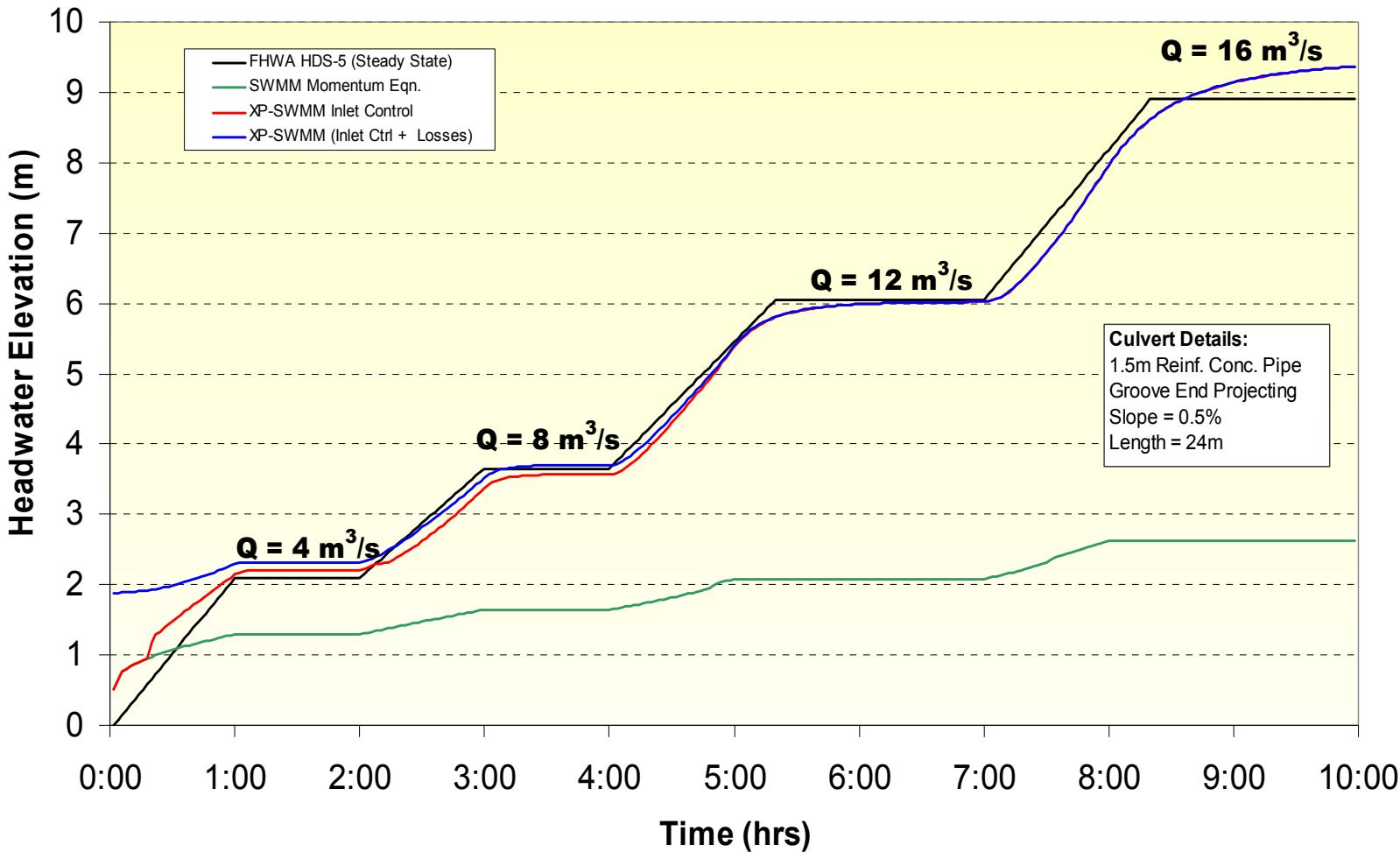
FHWA Inlet Control Equations for Culverts

- The head under inlet control may be significantly greater than that estimated assuming outlet control.
- XP-SWMM uses Inlet Control equations from the FHWA's "Hydraulic Design of Highway Culverts".
- Select from 58 inlet configurations



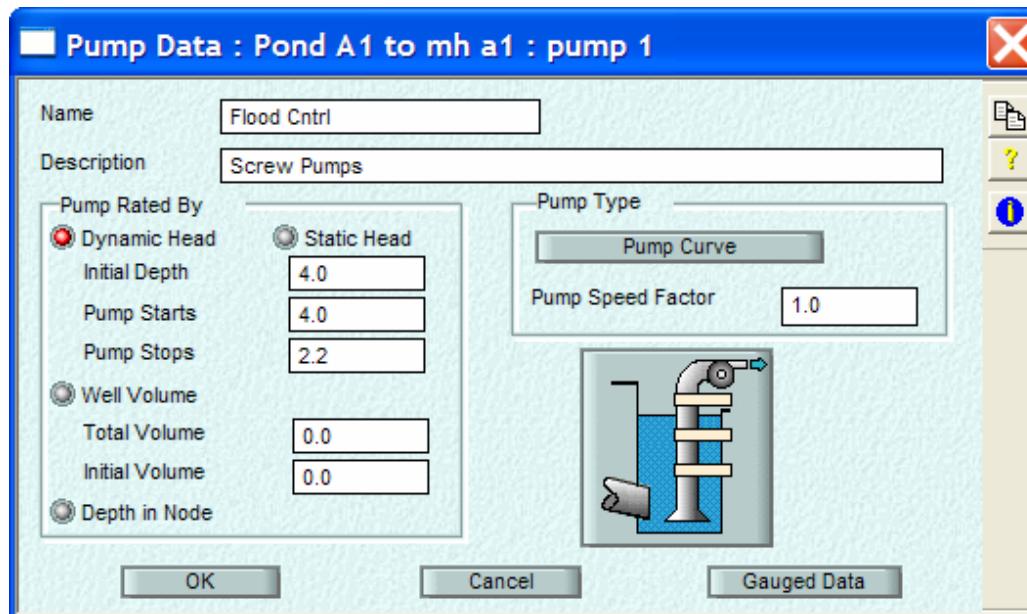
Inlet Control

Comparison of Culvert Headwater Elevation for Various Flow Control Conditions and Flow Rates

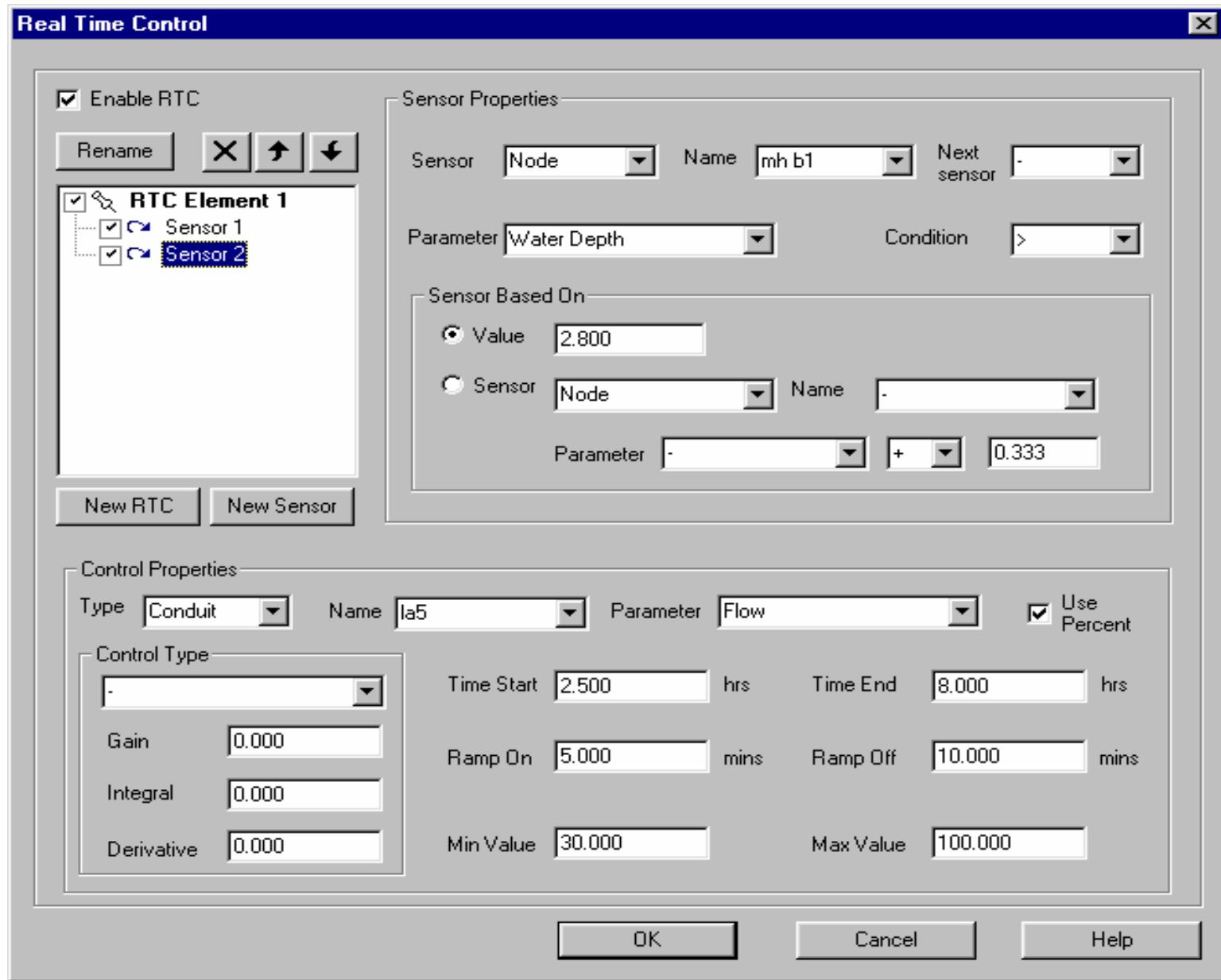


Pump Options

- Pump curves are stored in the Global Database
- Up to 7 pumps in a pump station
- Simulate variable speed pumps
- Generate flows based on pumping SCADA history



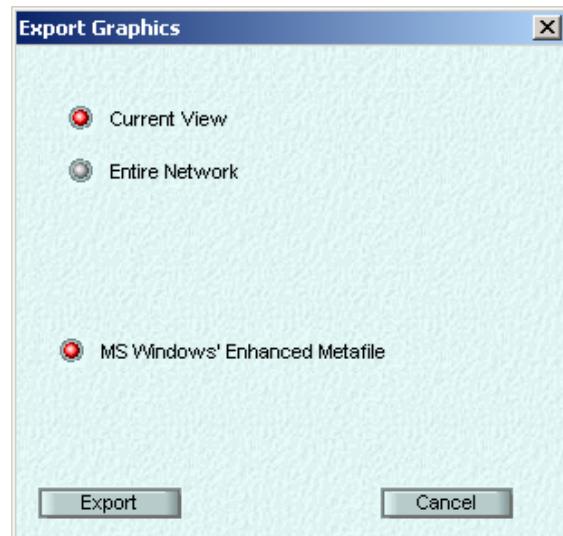
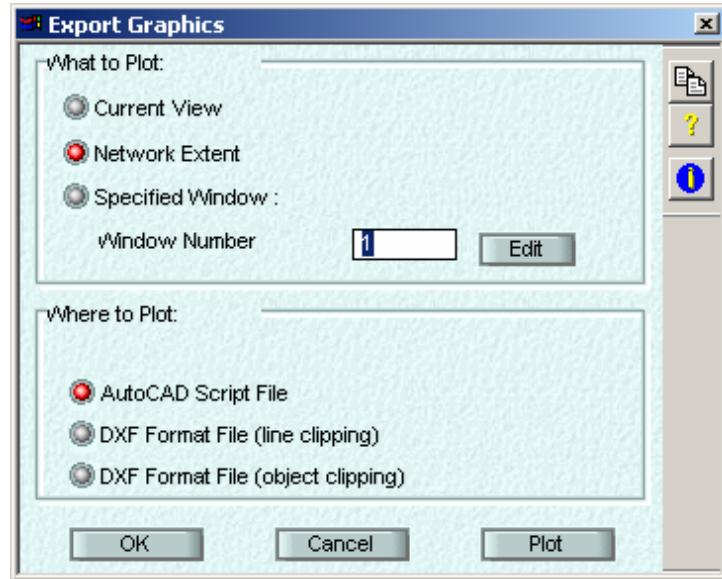
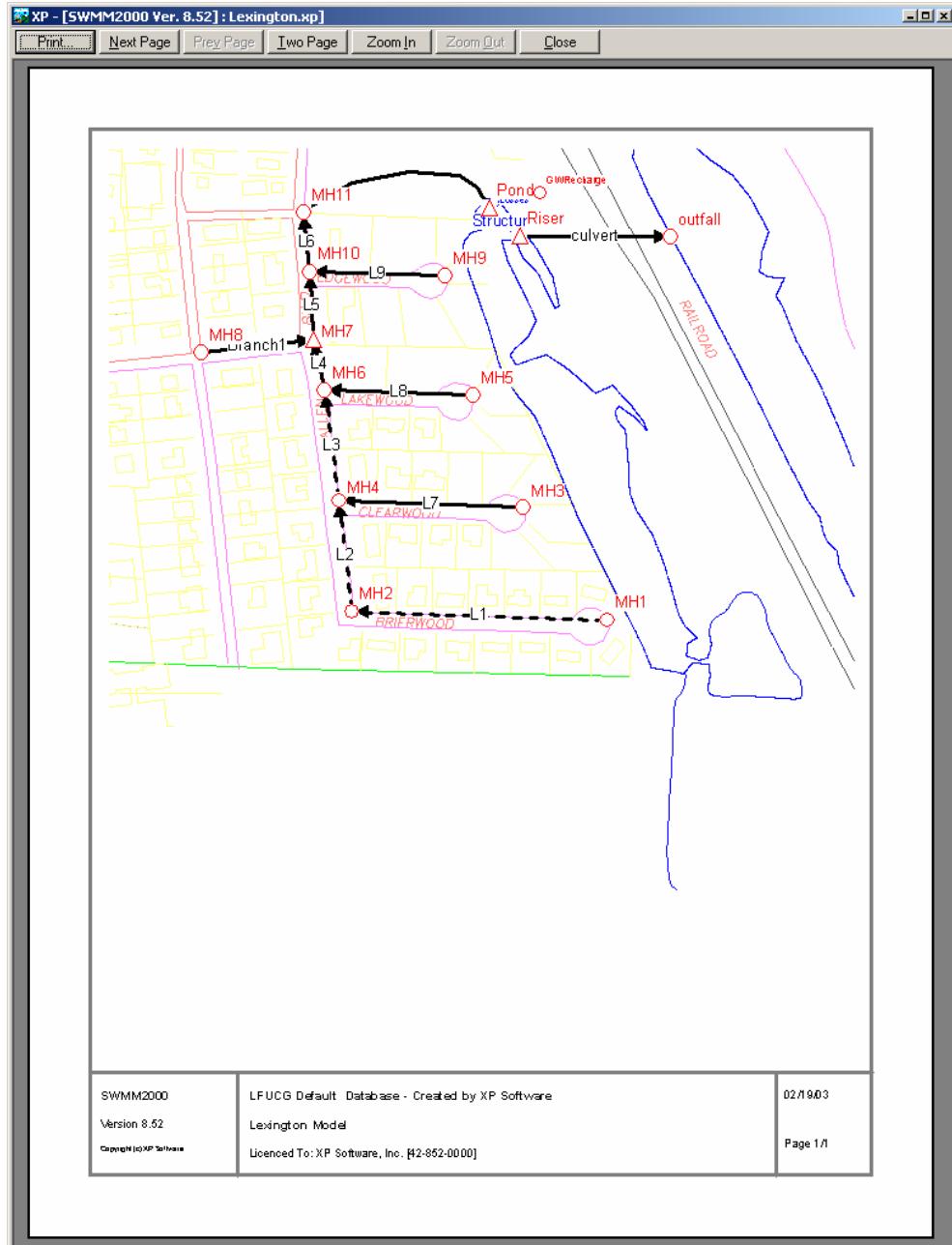
Real Time Control Module



“Public Friendly” DSS Tools

- Plan View Plotting and Plan View Export
- Comprehensive and Indexed Output File
- Review Results (Graphing of Time Series)
- Profile Plotting with Envelope of Maximums
- Dynamic Long Section View (Animation of HGL)
- Dynamic Section Views
- Dynamic Plan View
- Spatial Reports for Plan View Notation
- Graphical Encoding for Plan View Query
- Tabular Report (user-defined)
- XPX, RES and CSV Output to GIS or Databases
- XP Tables and Quick Data View Forms
- Interactive Analysis Engine & Run Time Graphing

Plan View Plotting and Export



XP SOFTWARE

Output File

| Table E20 - Junction Flooding and Volume Listing. |
| The maximum volume is the total volume |
| in the node including the volume in the |
| flooded storage area. This is the max |
| volume at any time. The volume in the |
| flooded storage area is the total volume |
| above the ground elevation, where the |
| flooded pond storage area starts. |
| The fourth column is instantaneous, the fifth is the |
| sum of the flooded volume over the entire simulation |
Units are either ft^3 or m^3 depending on the units.

Junction Name	Surcharged Time (min)	Flooded Time(min)	System Flooded Volume	Maximum Volume	Ponding Allowed Flood Pond Volume
1	0.0000	0.0000	0.0000	1205.3964	0.0000
2	0.0000	0.0000	0.0000	9.2705	0.0000

Simulation Specific Information
Number of Input Conduits..... 1 Number of Simulated Conduits..... 2
Number of Natural Channels..... 0 Number of Junctions..... 2
Number of Storage Junctions..... 1 Number of Weirs..... 0
Number of Orifices..... 0 Number of Pumps..... 0
Number of Free Outfalls..... 1 Number of Tide Gate Outfalls..... 0

| Average % Change in Junction or Conduit is defined as: |
| Conduit % Change => 100.0 (Q(n+1) - Q(n)) / Qfull |
Junction % Change => 100.0 (Y(n+1) - Y(n)) / Yfull
The Conduit with the largest average change was..FREE # 1 with 0.092 percent
The Junction with the largest average change was.2 with 1.487 percent
The Conduit with the largest sinuosity was.....3 with 0.673

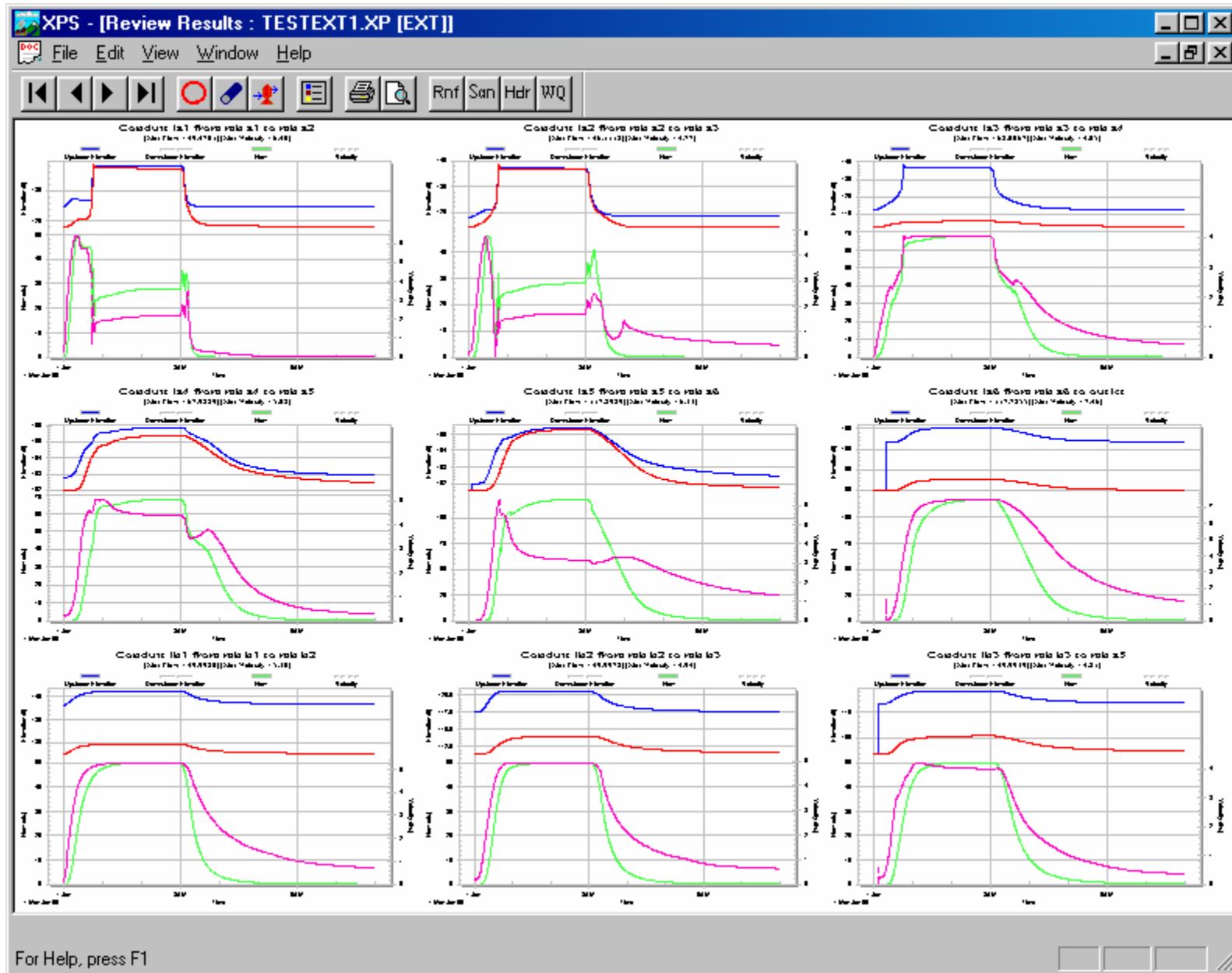
| Table E21. Continuity balance at the end of the simulation |
| Junction Inflow, Outflow or Street Flooding |
Error = Inflow + Initial Volume - Outflow - Final Volume

Inflow Junction	Inflow, ft^3	Average Inflow, cfs
1	10890.8333	3.0252

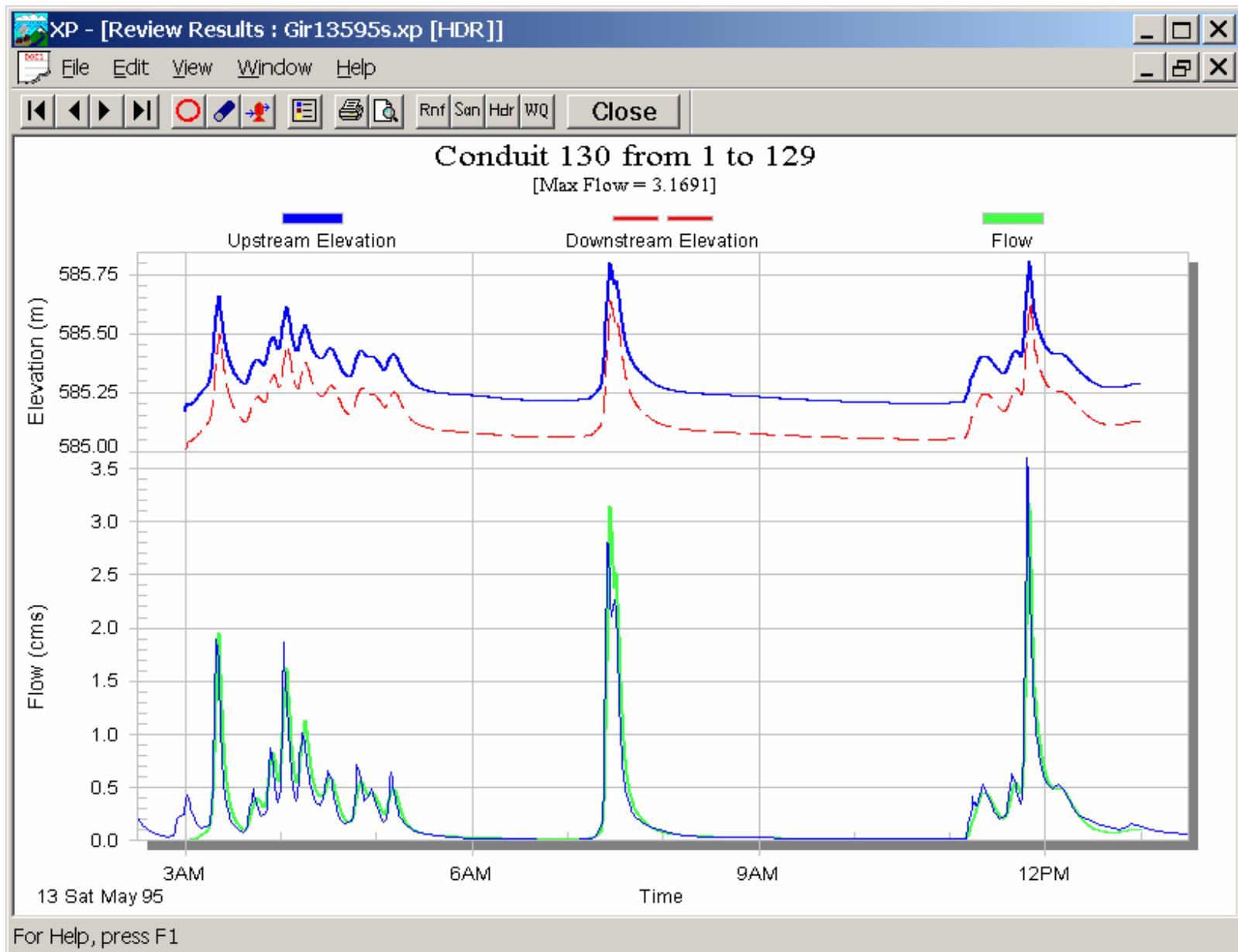
Outflow	Outflow	Average
1	10890.8333	3.0252

Unchanged INS Line 803, Column 91

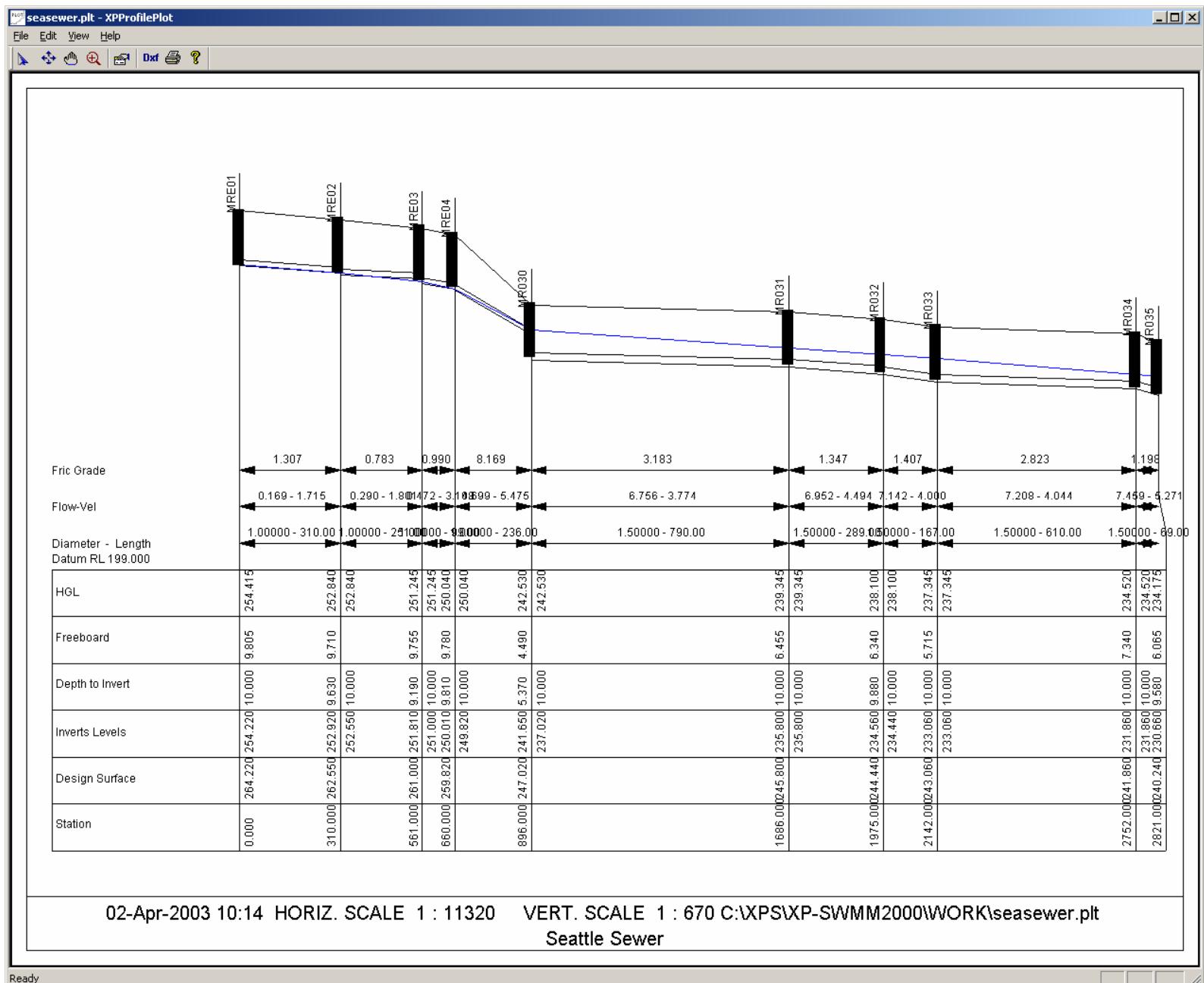
Review Results



Show Gauged Data



Profile Plotting Graphic



Profile Details

- Profile plots allow natural surface, design surface and services to be plotted

The image displays three windows from a civil engineering software interface:

- Link Design Surface**: A dialog box showing a table of coordinates for a design surface. The table has two columns: "Offset(x)" and "Elevation". The data is as follows:

Offset(x)	Elevation
0	135
20	135
50	136
80	134
120	136
150	137
160	140
180	142

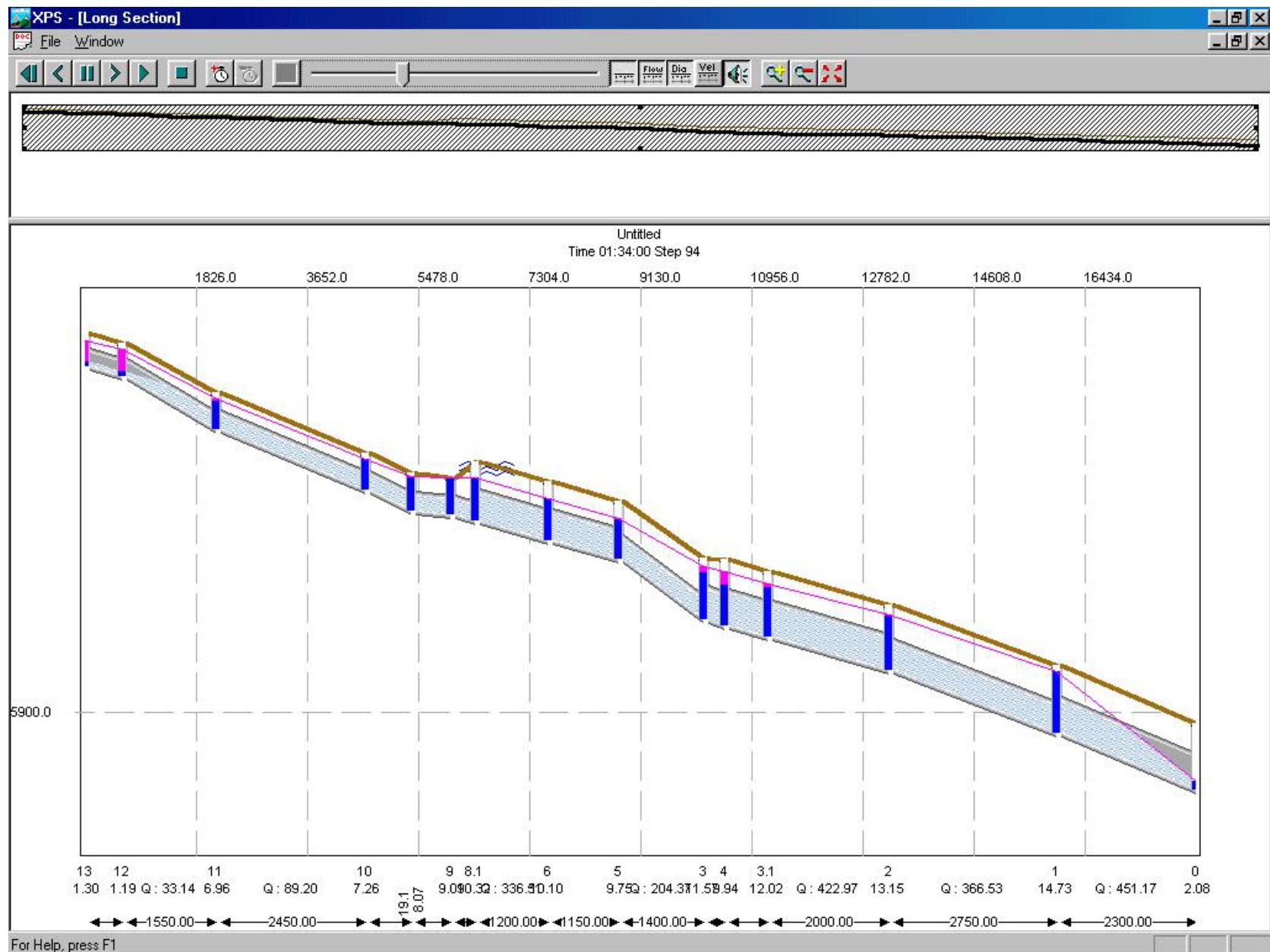
- TESTEXT1.plt - XPPProfilePlot**: A main window showing a 3D profile plot. The plot displays a green design surface, a red natural surface, and a blue base surface. A vertical dimension line indicates a height of 70.00 between the design and natural surfaces. The plot area includes coordinate markers for points m122 and m141. Below the plot, a table lists various parameters:

Frac Grade	6.786
Flow-Vel	33.517 - 5.451
Diameter - Legs	4.00000 - 100.
Datum RL 100.000	100.000 - 100.
HGL	100.000 - 100.
Freeboard	100.000 - 100.
Depth to invert	100.000 - 100.
Invert Elevation	100.000 - 100.
Design Surface	100.000 - 100.
Natural Surface	100.000 - 100.
Station	100.000 - 100.

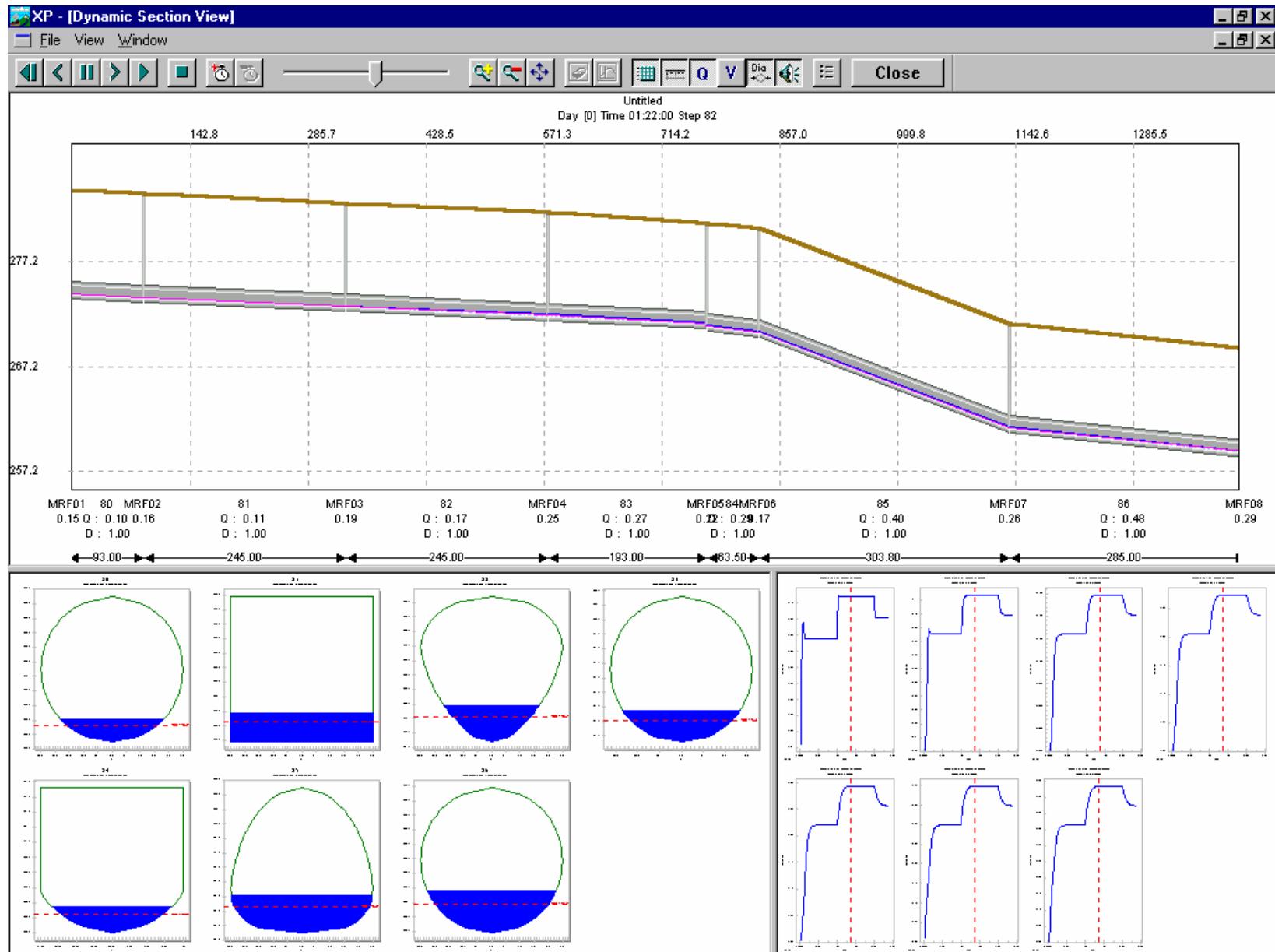
- Other Services**: A dialog box showing a 3D view of a trench with a gas pipe (GAS) and its properties table. The table has columns: Description, Diameter, Invert Elevation, Distance, and Location. One entry is shown:

Description	Diameter	Invert Elevation	Distance	Location
GAS	2	130	70	US

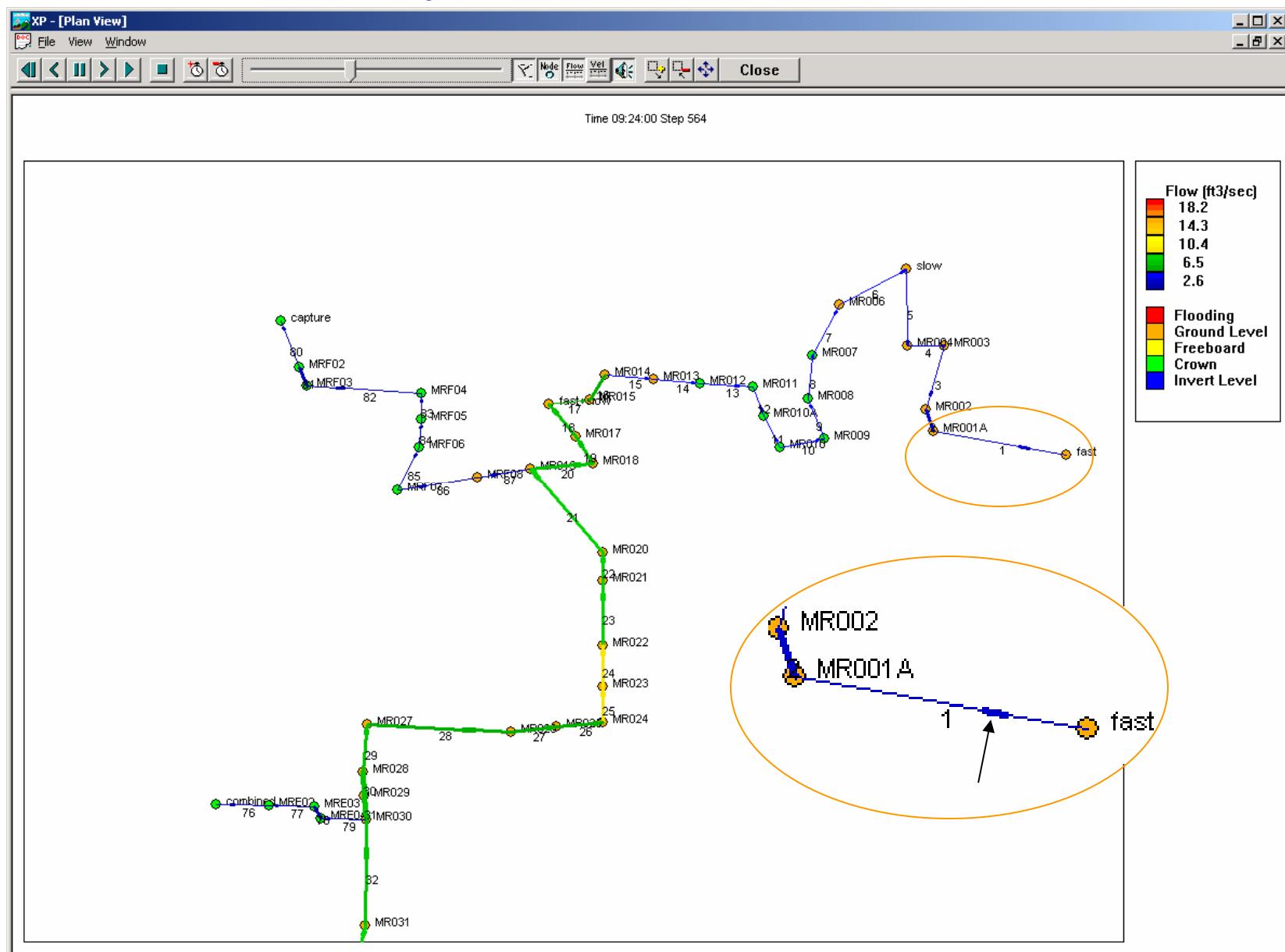
Dynamic Long-Section View



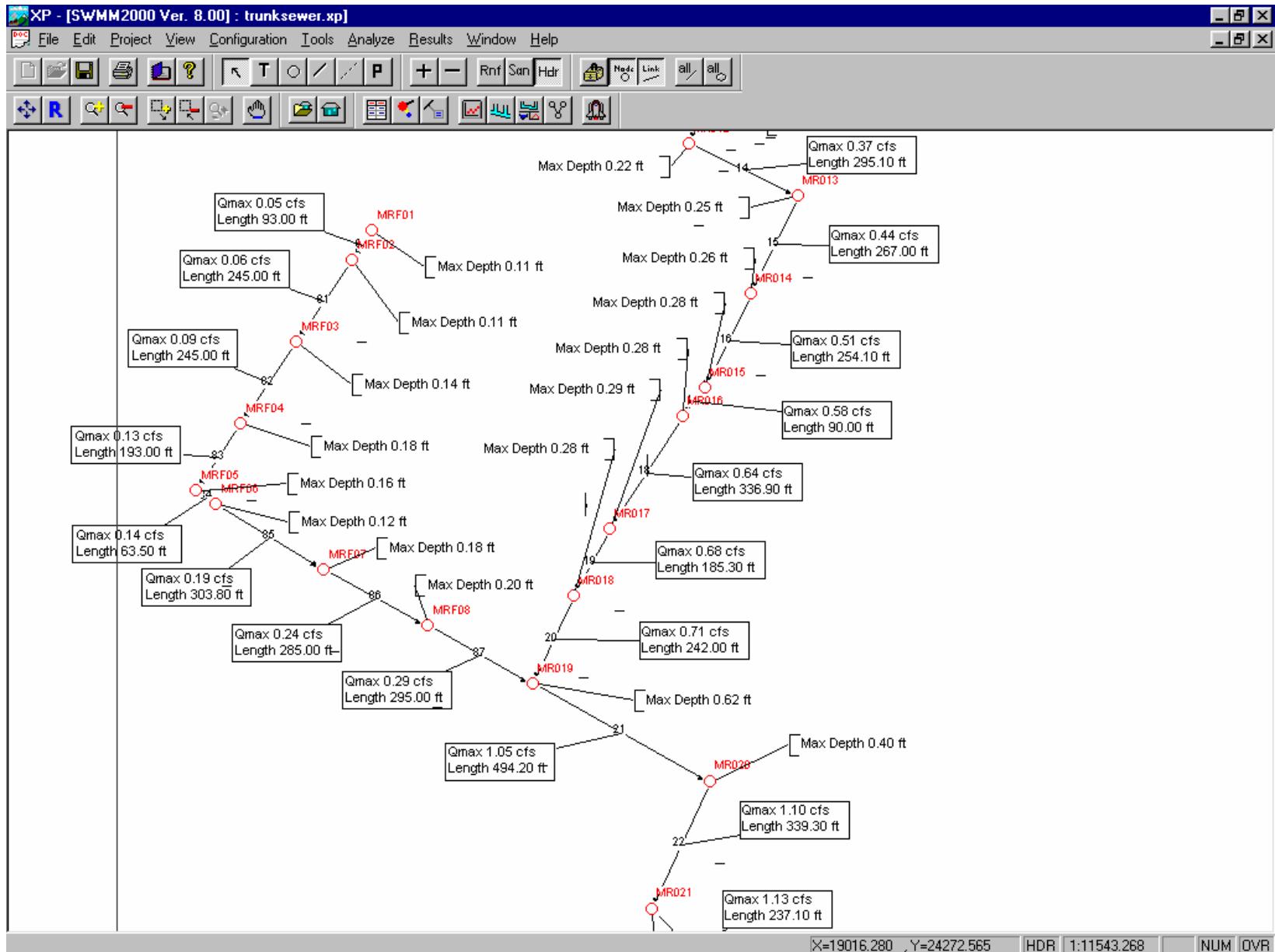
Dynamic Section Views



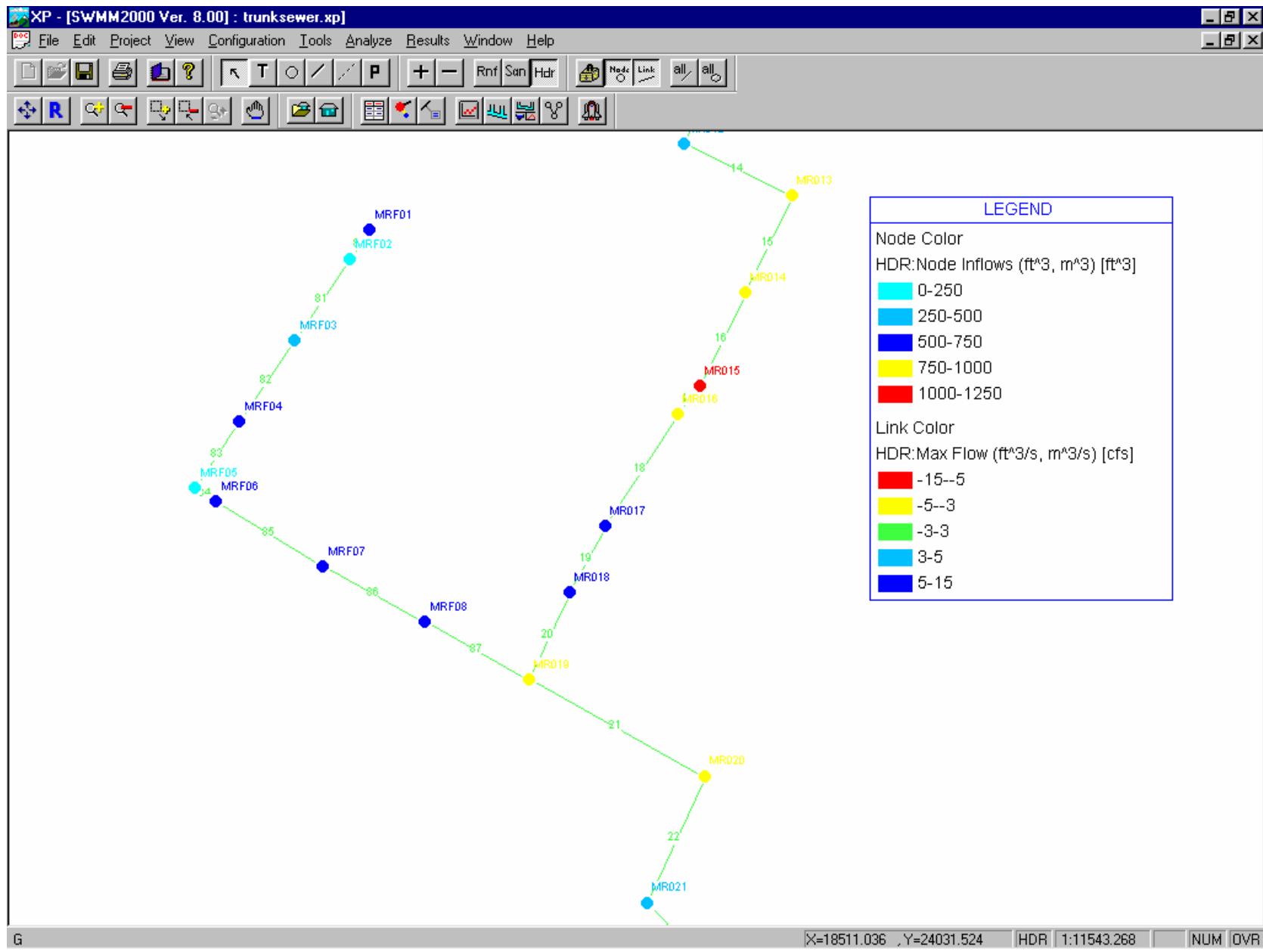
Dynamic Plan View



Spatial Reports



Graphical Encoding



Tabular Reports – Export to .CSV or .TXT

- Export report to text files .TXT or .CSV using icons or the Export menu
- Good link to GIS for model results

The screenshot shows a Windows application window titled "XPS". The menu bar includes "File", "Export", "Window", and "Help". Below the menu is a toolbar with two buttons: "TEXT" and "CSV". The main area displays a table titled "XP-SWMM2000 Hydraulics Table". The table has three main sections: "Link Name", "Link data", and "Link Results". The "Link Name" section contains columns for Link ID, USnode, DSnode, and Conduit type. The "Link data" section contains columns for Dia (m), Width (m), Roughness (%), Slope %, US invert leve (m), DS invert level (m), Peak flow (cms), and Max Velocity (m/s). The "Link Results" section contains values corresponding to the data in the previous sections. The table rows are numbered from 1 to 15, and the conduit type for all rows is listed as "Circular".

XP-SWMM2000 Hydraulics Table											
Link Name			Link data							Link Results	
Link	USnode	DSnode	Conduit type	Dia	Width	Roughness	Slope %	US invert leve	DS invert level	Peak flow	Max Velocity
1	MR001	MR001A	Circular	1.000	-	0.013	-	292.180	291.130	0.006	0.393
2	MR001A	MR002	Circular	1.000	-	0.013	-	291.130	290.270	0.047	1.459
3	MR002	MR003	Circular	1.000	-	0.013	-	290.270	288.250	0.068	1.694
4	MR003	MR004	Circular	1.000	-	0.013	-	288.250	286.880	0.139	2.999
5	MR004	MR005	Circular	1.000	-	0.013	-	286.880	284.930	0.140	2.345
6	MR005	MR006	Circular	1.000	-	0.013	-	284.930	283.880	0.198	2.677
7	MR006	MR007	Circular	1.000	-	0.013	-	283.880	281.740	0.199	2.695
8	MR007	MR008	Circular	1.250	-	0.013	-	281.740	278.300	0.254	3.369
9	MR008	MR009	Circular	1.250	-	0.013	-	278.120	277.260	0.273	2.587
10	MR009	MR010	Circular	1.250	-	0.013	-	277.120	275.690	0.280	2.668
11	MR010	MR010A	Circular	1.250	-	0.013	-	274.960	274.720	0.285	2.643
12	MR010A	MR011	Circular	1.250	-	0.013	-	274.610	272.580	0.335	2.415
13	MR011	MR012	Circular	1.250	-	0.013	-	272.580	271.570	0.341	2.440
14	MR012	MR013	Circular	1.250	-	0.013	-	270.920	268.830	0.372	2.529
15	MR013	MR014	Circular	1.250	-	0.013	-	268.110	266.470	0.438	2.491

XP Tables

- Exchange data with other programs and XP-Tables
- Create a Query by using filters

XP - [SWMM Ver. 9.00] : sea.xp:2 (Table)

File Edit View Options Format Window Help

Base Scenario

Name	Scenario	Node Name	Ground Elevation (Spill Crest)	Max Water Elevation (ft, m)	Freeboard (ft, m)	Max Surface Area (ft ² , m ²)	Mean Nodal Iterations	Total Iterations
combined	Base Scenario	combined	264.22	264.22	0.00	12.57	1.05	41263.000
MRE02	Base Scenario	MRE02	262.55	258.90	3.65	12.57	1.08	42372.000
MRE03	Base Scenario	MRE03	261.00	254.19	6.81	12.57	1.09	42619.000
MRE04	Base Scenario	MRE04	259.82	252.16	7.66	12.57	1.31	51245.000
fast	Base Scenario	fast	302.18	299.93				
MR001A	Base Scenario	MR001A	301.00	296.93				
MR002	Base Scenario	MR002	300.27	296.16				
MR003	Base Scenario	MR003	297.53	293.86				
MR004	Base Scenario	MR004	296.09	292.69				
slow	Base Scenario	slow	294.57	289.34				
MR006	Base Scenario	MR006	293.81	285.86				
MR007	Base Scenario	MR007	289.81	282.41				
MR008	Base Scenario	MR008	288.12	281.14				
MR009	Base Scenario	MR009	287.12	280.29				
MR010	Base Scenario	MR010	284.96	279.57				
MR010A	Base Scenario	MR010A	284.81	278.87				
MR011	Base Scenario	MR011	282.58	278.17				
MR012	Base Scenario	MR012	280.92	277.23				
MR013	Base Scenario	MR013	278.11	276.39				
MR014	Base Scenario	MR014	276.47	275.38				
MR015	Base Scenario	MR015	274.58	274.58				
fast+slow	Base Scenario	fast+slow	273.75	273.66				
MR017	Base Scenario	MR017	270.69	270.69				
MR018	Base Scenario	MR018	269.02	269.02				
capture	Base Scenario	capture	283.98	278.59				
MRF02	Base Scenario	MRF02	283.65	277.21				
MRF03	Base Scenario	MRF03	282.79	276.61				

Filter

Compare Type	Field	Operation	Value	Object	Join
Value	Time of Maximum HGL (hrs)	>	2.5		AND
Value	Freeboard (ft, m)	<=	1		AND

Insert Delete

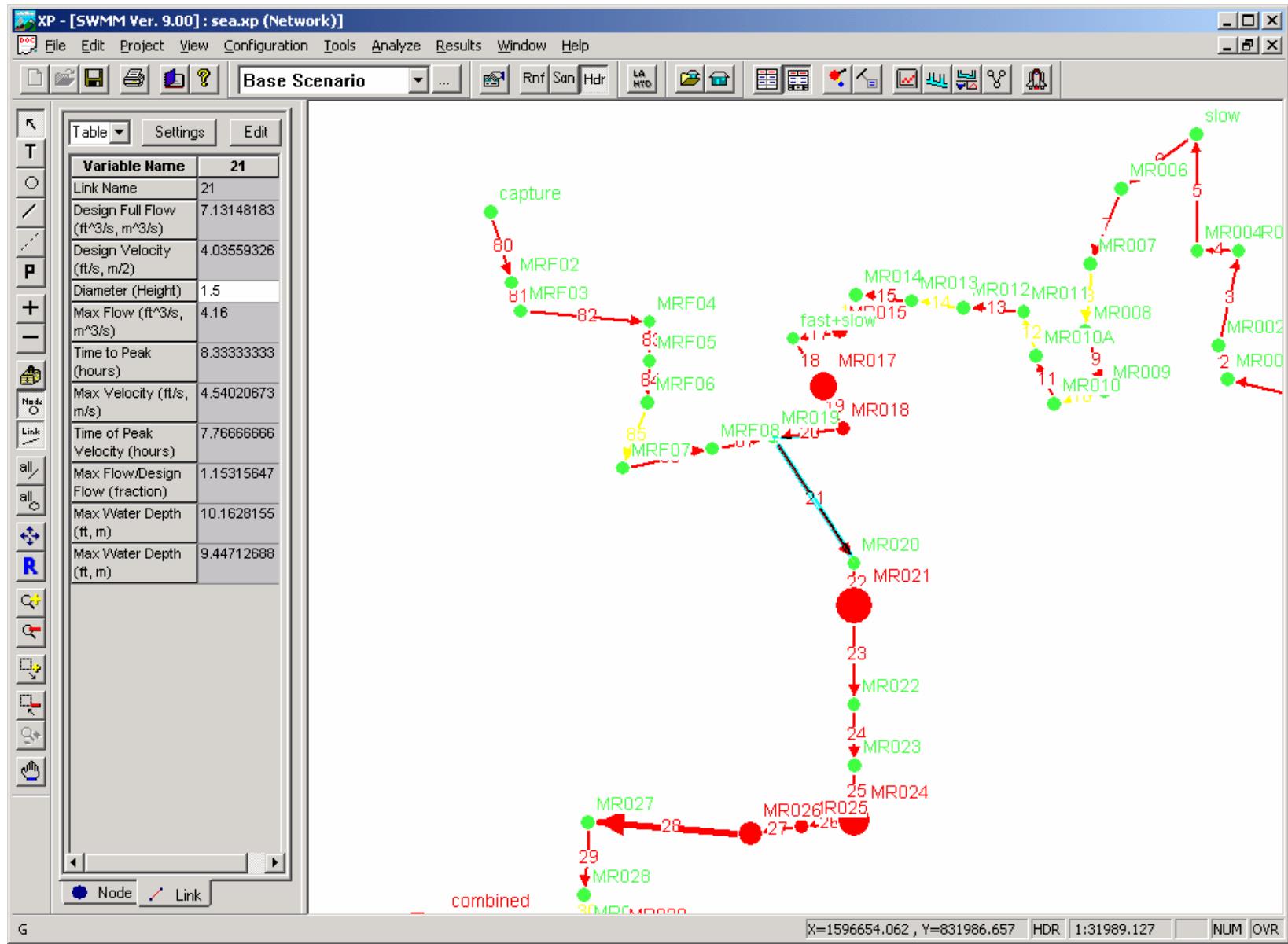
OK Cancel

6.18 12.57 1.04 40825.000

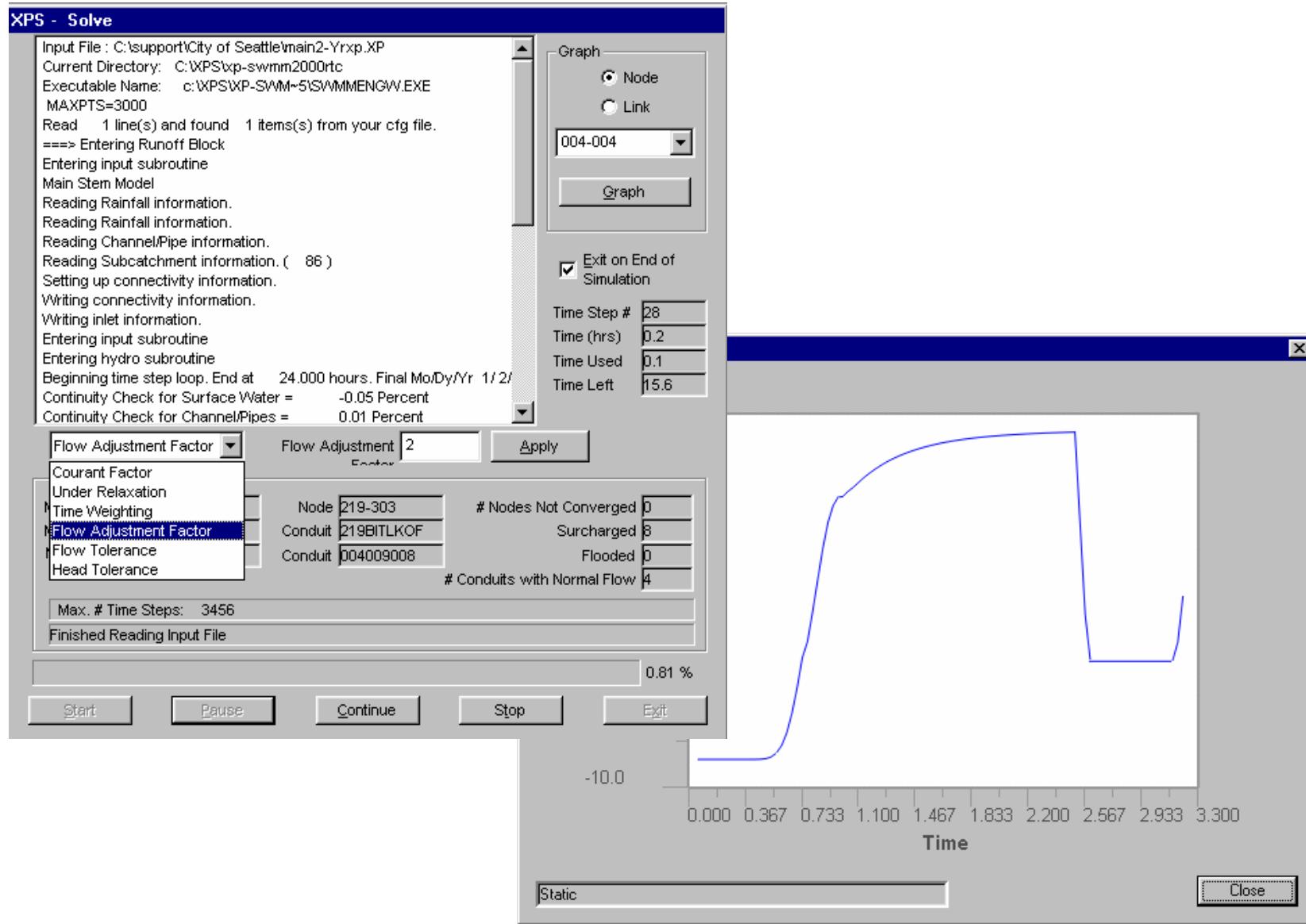
Table E4 Table E8/E9 Table E10 Table E11 Table E1

NUM OVR

Quick Data View

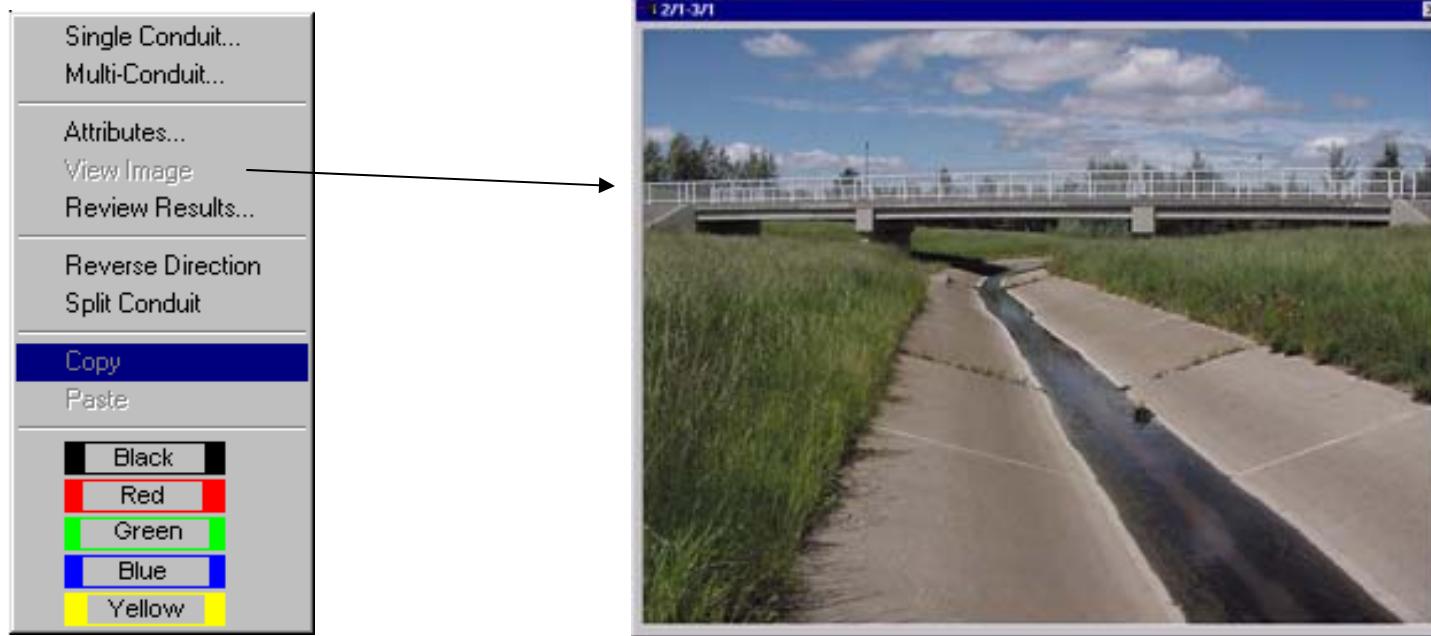


Interactive Analysis Engine and Runtime Graphing



Attach Images to Links and Nodes

- XP-SWMM supports images attached to both NODES and LINKS in the network. This feature is extremely useful when working on large projects with a range of photographs available.
- Most of the standard windows image file types are supported, ranging from BMP, JPG through to TIFF.



Dynamic with Link to External Data: XP-GIS

GIS Module

The image displays the XP-GIS software interface, which integrates a network editor, a data viewer, and a map viewer.

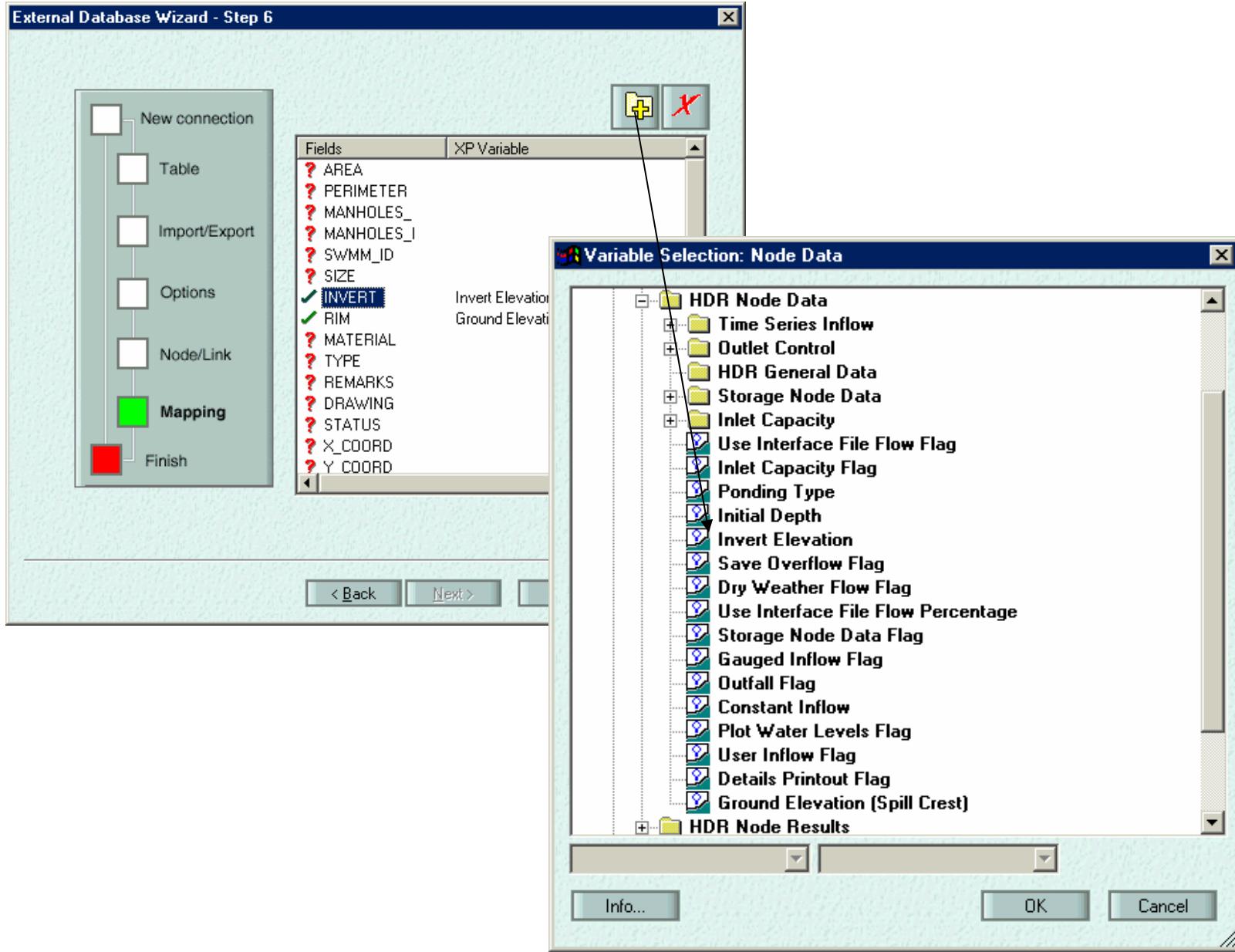
Network Editor: On the left, there is a tree view of network components: Nodes, Links, Areas, and Areas with Labels. Below it is a detailed view of a network segment with nodes, links, and specific attributes like 'Flow' and 'Demand'. A legend on the right identifies symbols for Nodes, Links, Areas, and Areas with Labels.

Data Viewer: In the top right, there is a Microsoft Excel spreadsheet titled "H1032 - 295_1206". The columns represent attributes such as FNODE, TNODE, LPOLY, RPOLY, LENGTH, MAINS_, MAINS_ID, SWMM_ID, SIZE, TYPE, MATERIAL, OWNER, and SHAPE. The data lists various network segments with their corresponding values.

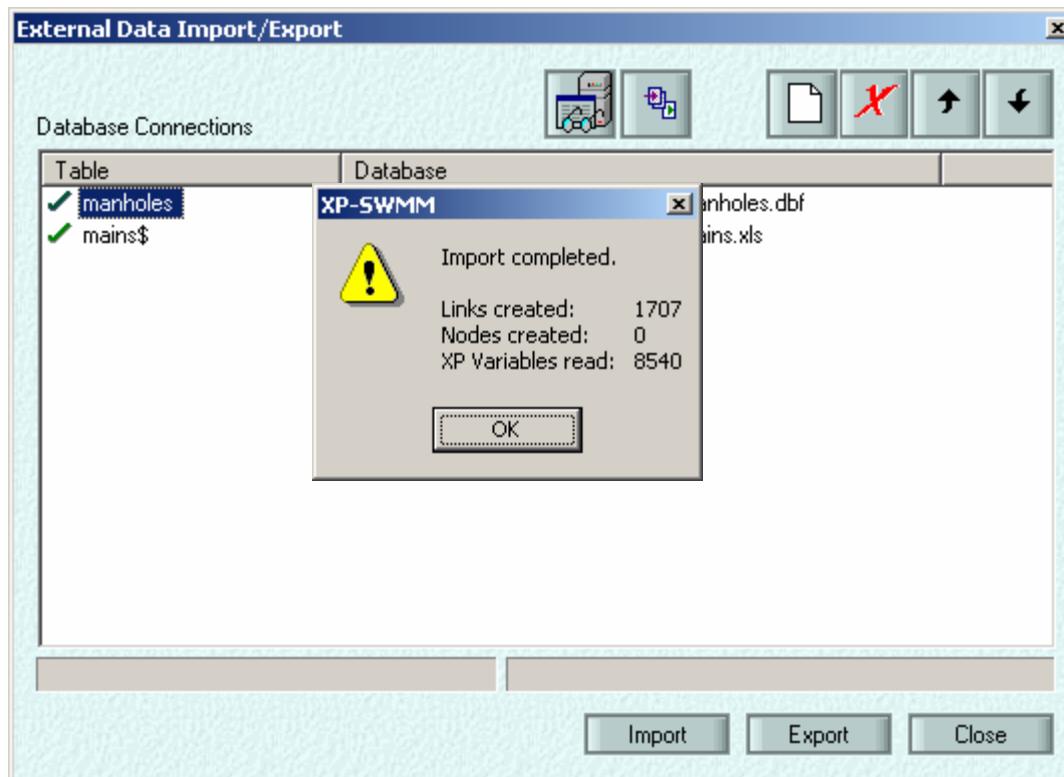
Map Viewer: The bottom half of the screen shows a map of a geographic area. The network segments are overlaid on the map, each labeled with its unique ID (e.g., 109405957, 109405951, 109405959, etc.). The map also includes a coordinate grid and a scale bar.

Integration: Two large green arrows point from the Excel table and the map towards the central network diagram, illustrating the dynamic link between external data and the GIS module.

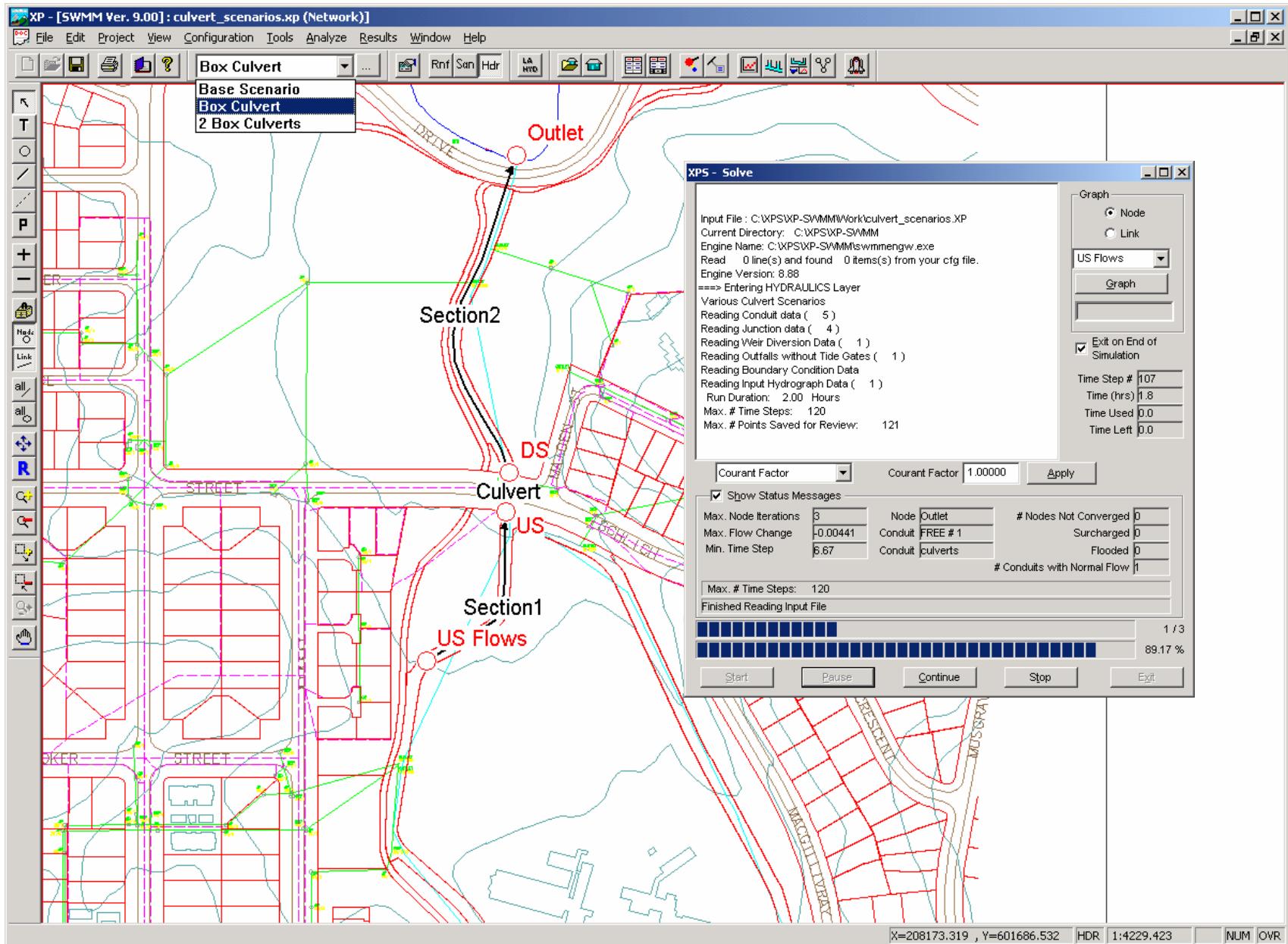
Map your data to the XP database definitions



*Once configured a simple click allows
data to be imported, exported and updated*

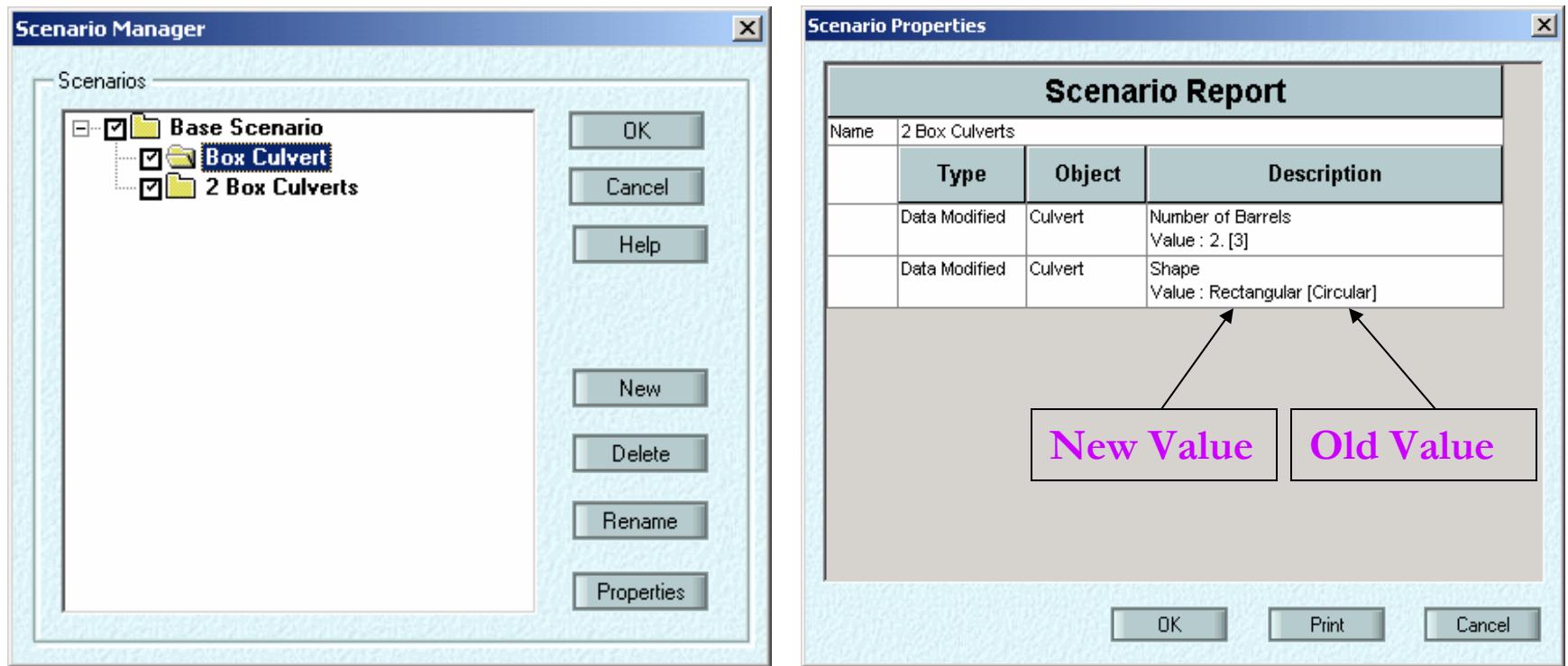


Scenario Manager-Multiple Runs

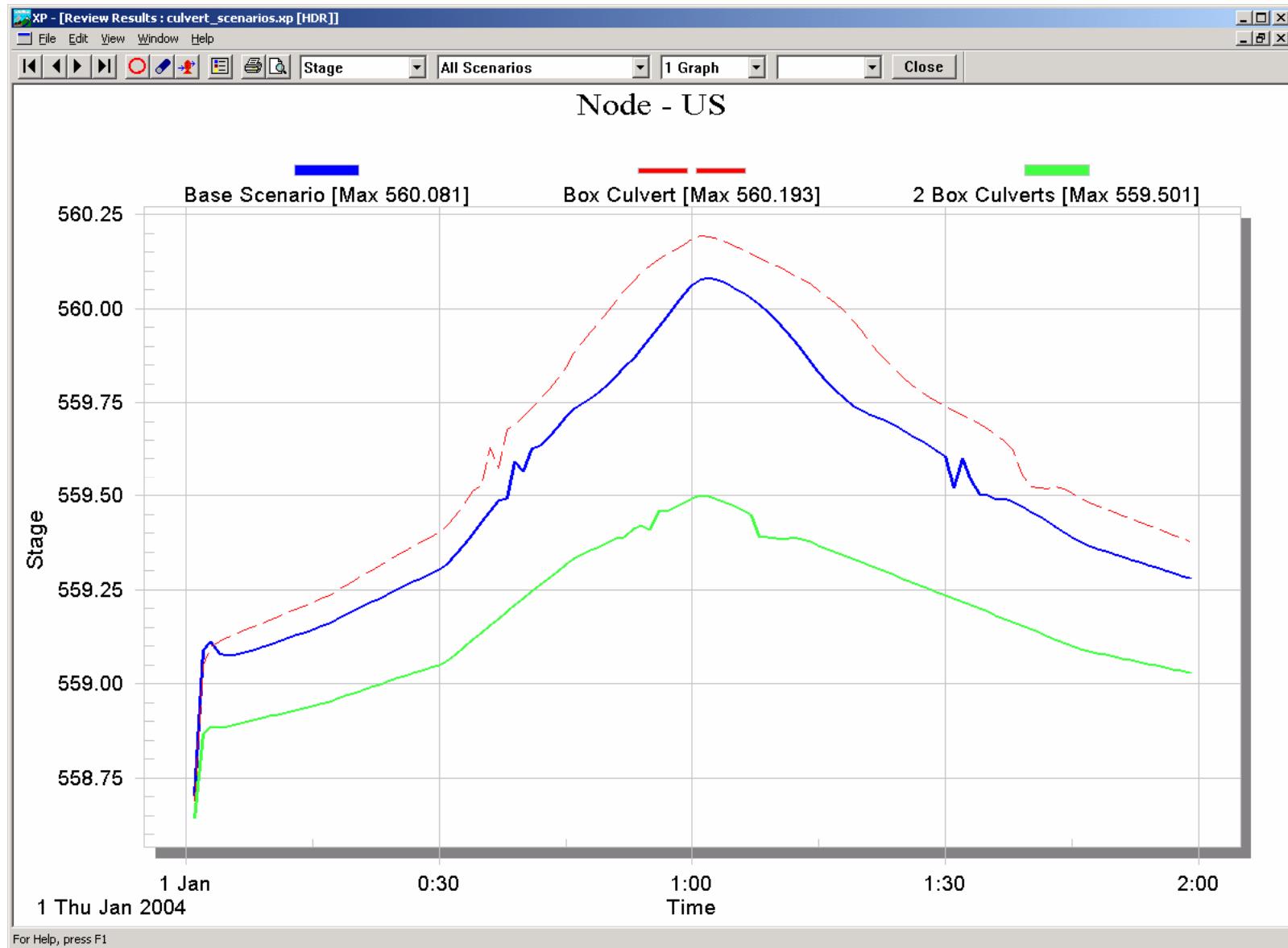


Scenario Manager-Management and Reports

- Add, Delete and Activate Scenarios in the Manager Dialog
- Scenario Properties Track Changes Automatically



Scenario Manager- Series of Review Results



Scenario Manager – Multiple Results in Tables

XP - [SWMM Ver. 9.00] : culvert_scenarios.xp:2 (Table)

File Edit View Options Format Window Help

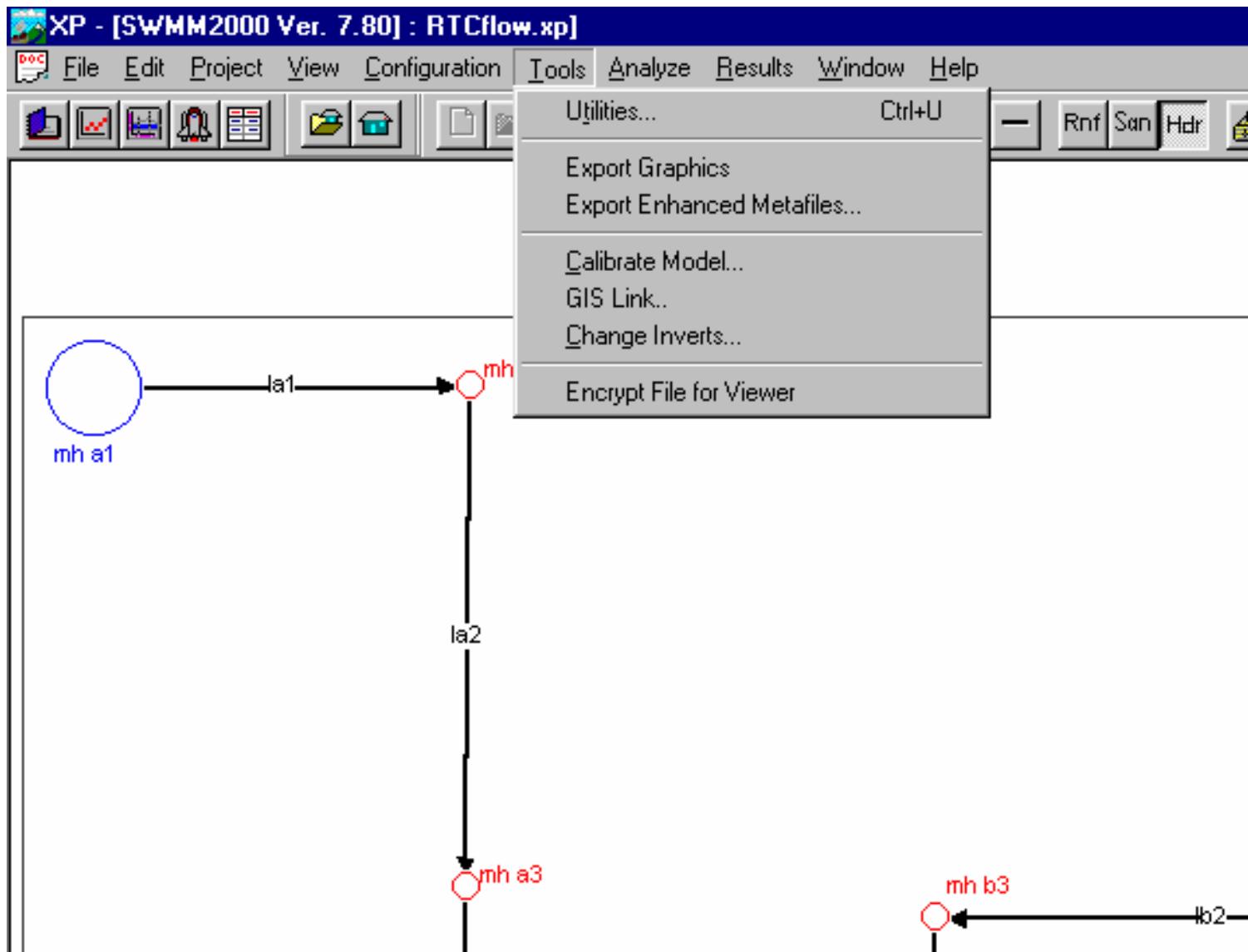
ALL Scenarios

Name	Scenario	Shape	Diameter (Height)	Number of Barrels	Length	Max Flow (ft^3/s, m^3/s)	Weir Name	Weir Crest Elevation	Max Water Elevation (ft, m)
Section1	Base Scenario	Natural	0.75	1.0	150.00	5.96			562.03
	Box Culvert					5.97			562.05
	2 Box Culvert					5.96			561.96
culverts	Base Scenario	Rectangular	1.00	2.00	31.00	5.75			560.08
	Box Culvert					5.37			560.19
	2 Box Culvert					5.95			559.50
Overtop	Base Scenario						Overtop	560.00	560.08
	Box Culvert								560.19
	2 Box Culvert								559.50
Section2	Base Scenario	Natural	1.50	1.0	270.00	5.91			559.19
	Box Culvert					5.94			559.19
	2 Box Culvert					5.94			559.19

Culvert Detail /

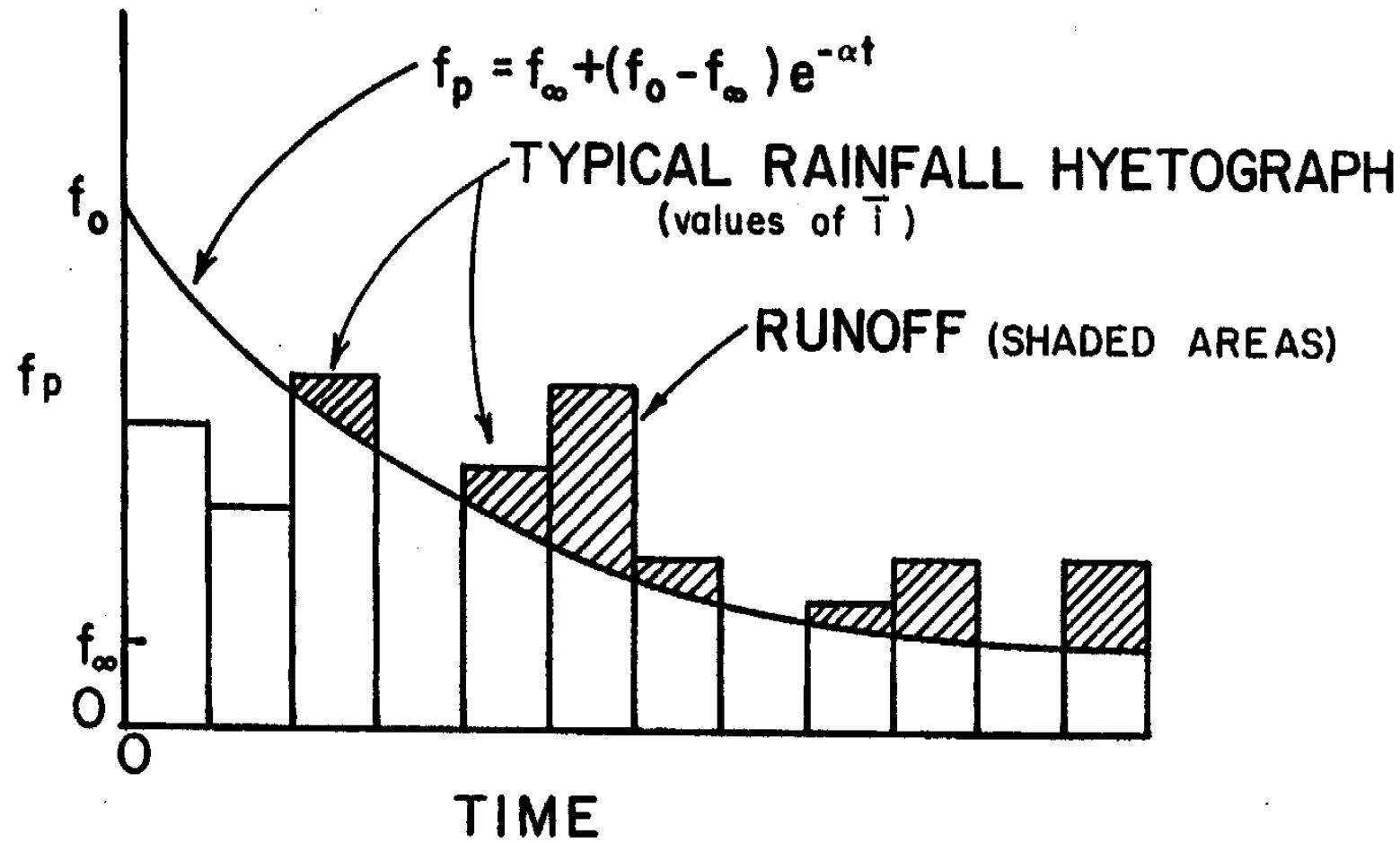
NUM OVR

Encryption for XP-Viewer

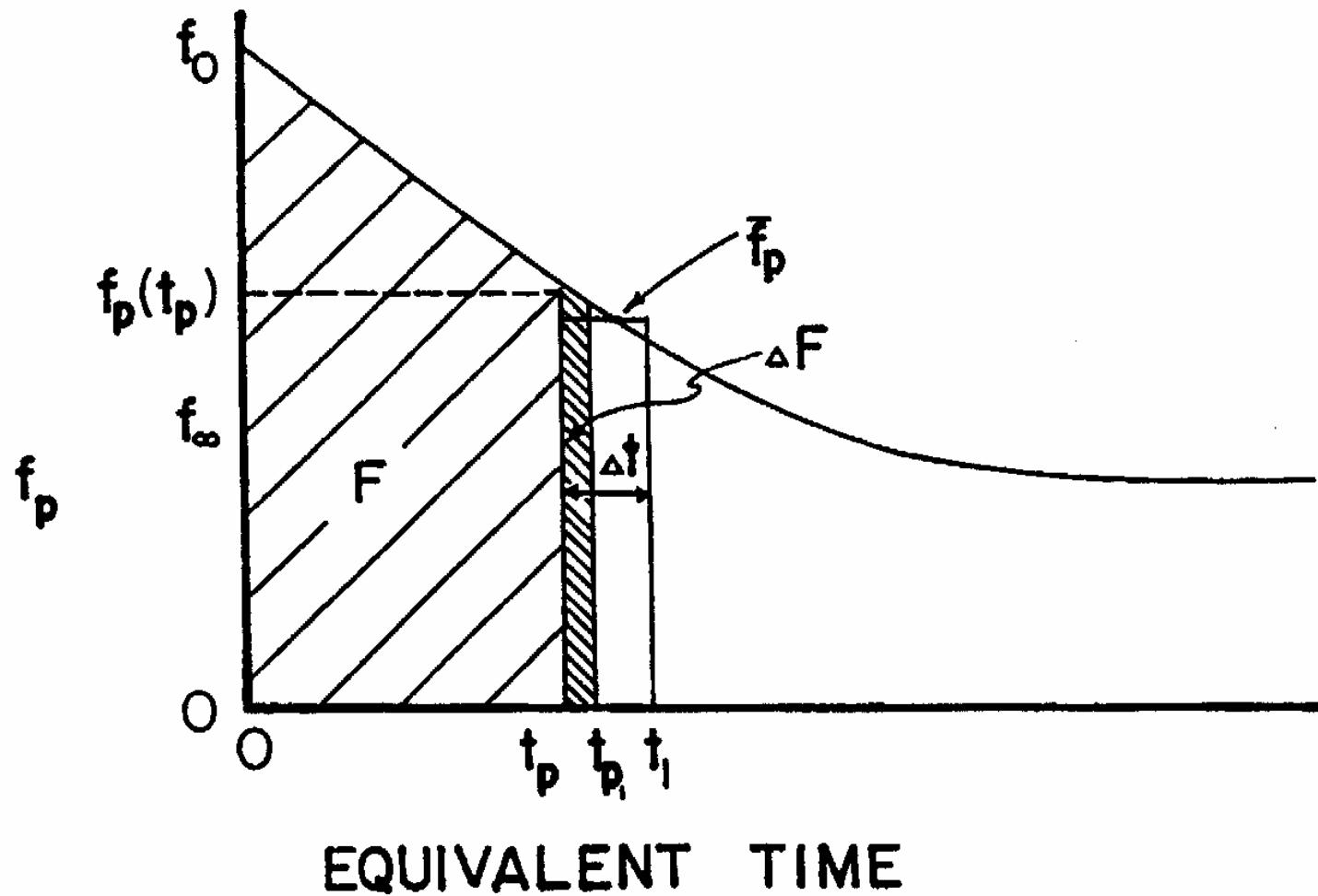


Slides for Specific Questions

Horton Infiltration Curve



Horton Equivalent Time



Green-Ampt Equation

For $F < F_s$: $f = i$ and $F_s = S_u \text{IMD} / (i/K_s - 1)$ for $i > K_s$
and no calculation of F_s for $i < K_s$

For $F > F_s$: $f = f_p$ and $f_p = K_s(1 + S_u \text{IMD}/F)$

Where:

f = infiltration rate, ft/sec,

f_p = infiltration capacity, ft/sec,

i = rainfall intensity, ft/sec,

F = cumulative infiltration volume, this event, ft,

F_s = cumulative infiltration volume to cause surface saturation, ft,

S_u = average capillary suction at the wetting front (SUCT), ft water,

IMD = initial moisture deficit for this event (SMDMAX), ft/ft, and

K_s = saturated hydraulic conductivity of soil, (HYDCON) ft/sec.

Powerful Network Editing

Split Links
Reverse Direction
Calculate Slope
Calculate Length

